DESIGN OF A HOLLOW DAM AND HYDRO-ELECTRIC PLANT AT FRENCH'S MILLS N. Y.

BY

F. C. ARMSTRONG

L. L. EDLUND

O. G. O'GRADY

ARMOUR INSTITUTE OF TECHNOLOGY

1916

621.312
Ar 6

Illinois Institute
of Technology
UNIVERSITY LIBRARIES

AT 400
Armstrong, F. C.
Design of a hollow dam and
hydro-electric plant at

For Use In Library Only

DESIGN OF A HOLLOW DAM AND
HYDRO - ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.

A THESIS

PRESENTED BY

Fred C. Armstrong

Lawrence L. Edlund

Omar G. O'Grady

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

CIVIL ENGINEERING

APPROVED:

Alfred E. Phillips
PROFESSOR OF CIVIL ENGINEERING

H M Raymond
DEAN OF ENGINEERING STUDIES

DEAN OF CULTURAL STUDIES

DATE May 22nd 1916

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

6[illegible]2
[illegible]

TABLE OF CONTENTS

Preface 1
Preliminary Studies 3
Hydraulic Calculations 10
Design of Dam 17
Design of Pipe Line and Intake 33
Design of Power House 45
    Turbine 47
    Scroll Case 50
    Draft Tube 59
    General Layout 63
    Column Design 67
    Crane Beam 70
    Lintels 71
    Floor Slab for Balcony 72
    Supporting Walls for Balcony . . . 73

26448

PREFACE

In the selection and preparation of this thesis, the authors have sought to secure one which would involve the solution of as many different problems as possible: the idea has been not so much to plan, in general, some large water power development, but to work out in detail the problems connected with a small installation and to make a complete set of construction drawings for it. No attempt has been made to design any of the electrical or hydraulic equipment of the plant as this would present a very large problem in itself, but these have been selected with care and reference to their fitness for the work which they are to do. The factors entering into the choice of all such equipment, however, and the reasons for the selection made will be included in this work.

The major part of this thesis will, therefore, consist of the following parts:

Preliminary Studies
Hydraulic Calculations
Design of Dam
Design of Pipe Line and Intake
Design of Power House

We desire in this place to make acknowledgment of our indebtedness of Professor Stanley Dean of the Civil Engineering Department through whose kindness we secured much valuable data in regard to conditions at French's Mills, and also for many suggestions throughout the course of our work.

F. C. Armstrong
L. L. Edlund
O. G. O'Grady

May 25, 1916.

PRELIMINARY STUDIES

The location of the proposed development is at French's Mills, New York, about twelve miles west of Albany and south of Schenectady. It lies near to a manufacturing district, and there are also a number of towns within a radius of ten miles of the proposed site. These should supply a sufficient power and lighting load to permit of the operation of the plant during at least twenty hours per day.

The power site is on the Normanskill, which is at this point about eighty feet wide. The main line of the West Shore R. R. is only a few hundred feet below the dam site. The selection of this particular location was made because of the building of a water-supply dam at this point which made it possible to secure considerable accurate data as to the topography at the dam site and other general conditions which could not have been ascertained without a somewhat extended visit to the site.

The present water-supply dam is thirty-six feet high, and a study of the topography along the stream, as well as consideration of the fact that the surrounding country is valuable for fruit growing, lead to the belief that this was the maximum head that could be secured by a dam at this point. This site also made it possible to secure an increased head by running a pipe line from the dam to a point about 1500 feet downstream where the power house could be located. It was therefore decided to construct a 36 ft. dam and to run a pipe line to the power house, thereby gaining about thirty-three feet. It It was also decided to increase the storage capacity of the dam by placing three feet of flash boards above the crest of the dam and also thereby increasing the maximum available head to seventy-two feet.

The ground throughout the vicinity of the development is of limestone rock in hor-

izontal strata, with a maximum earth covering of about three feet. These conditions make the problem of foundations a comparatively easy one, both for the dam and the power house. Test bits were sunk at several places at the dam site by the engineers for the water-supply dam and showed the rock to be entirely reliable and uniform.

As far as was ascertainable, the only government records of the flow of this stream were taken in 1891. A tabulation of the average monthly run-off during that period is as follows:

Month	Cu. Ft. per Sec.
Jan.	No Record
Feb.	" "
Mar.	" "
Apr.	" "
May	" "
Jun.	26.2
Jul.	10.2
Aug.	8.7
Sep.	8.1
Oct.	10.6
Nov.	21.7
Dec.	57.2

It was found, however, that daily records of stream flow had been taken during a period of five years by an engineer living in the vicinity, and from his report, the following figures were secured:

Month	Cu. Ft. per Sec.
Jan.	205
Feb.	325
Mar.	390
Apr.	275
May	275
Jun.	70
Jul.	28
Aug.	8
Sep.	32
Oct.	170
Nov.	245
Dec.	230

This engineer states that he believes the government readings of 1891 far below the average, and inasmuch as his records cover a period of five years, they are probably much more reliable. These figures plotted in the form of a run-off curve are shown in Figure 1, and will form the basis for the calculations of the power possibilities of this site.

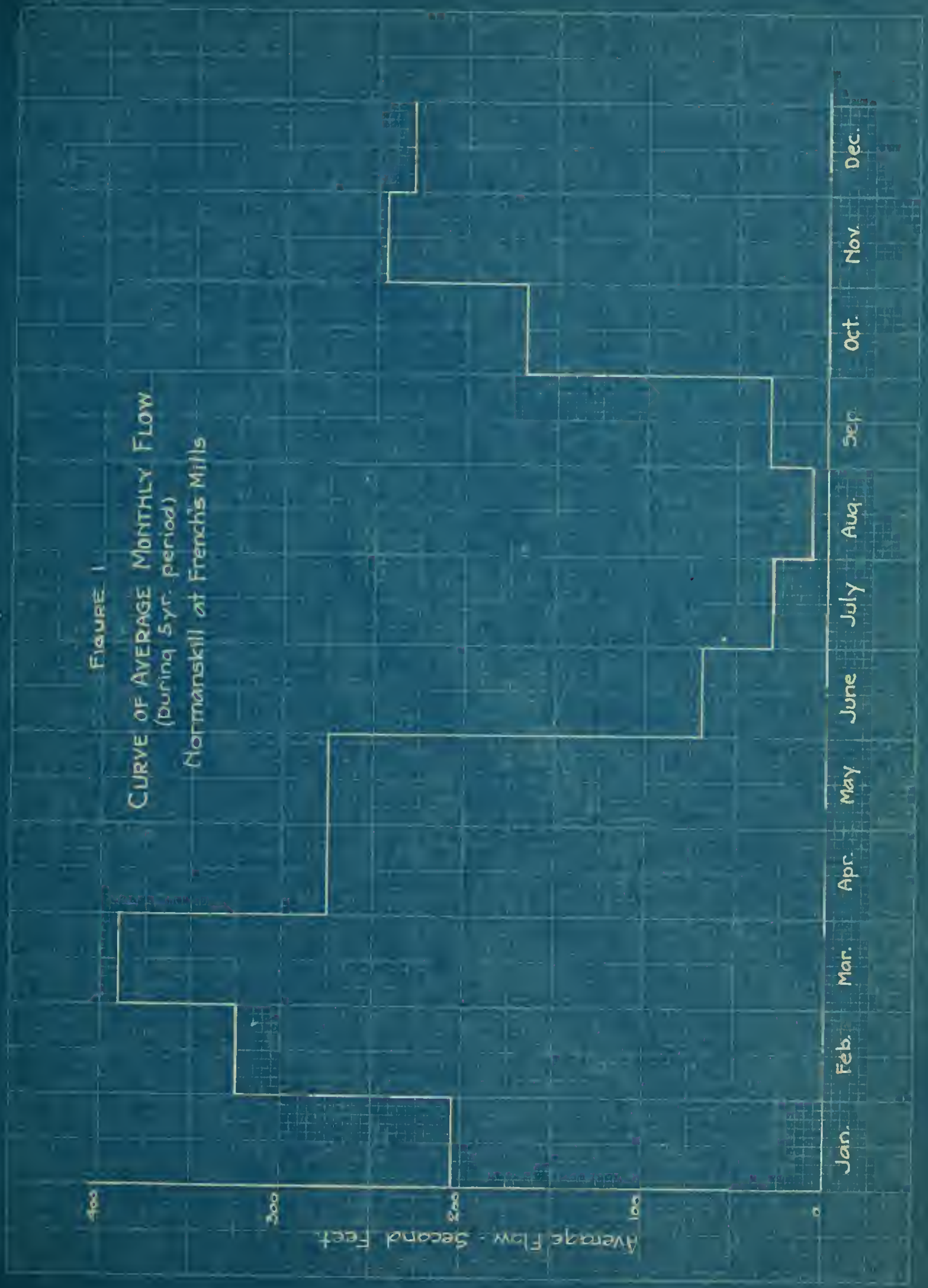


FIGURE I

CURVE OF AVERAGE MONTHLY FLOW
(During 5 yr. period)
Normanskill at French's Mills

The location of the dam, pipe line and power house are shown in a general way on Fig. 2, and to a larger scale and with more detail on Plate I. The topography at the site of the dam is shown on Plate II.

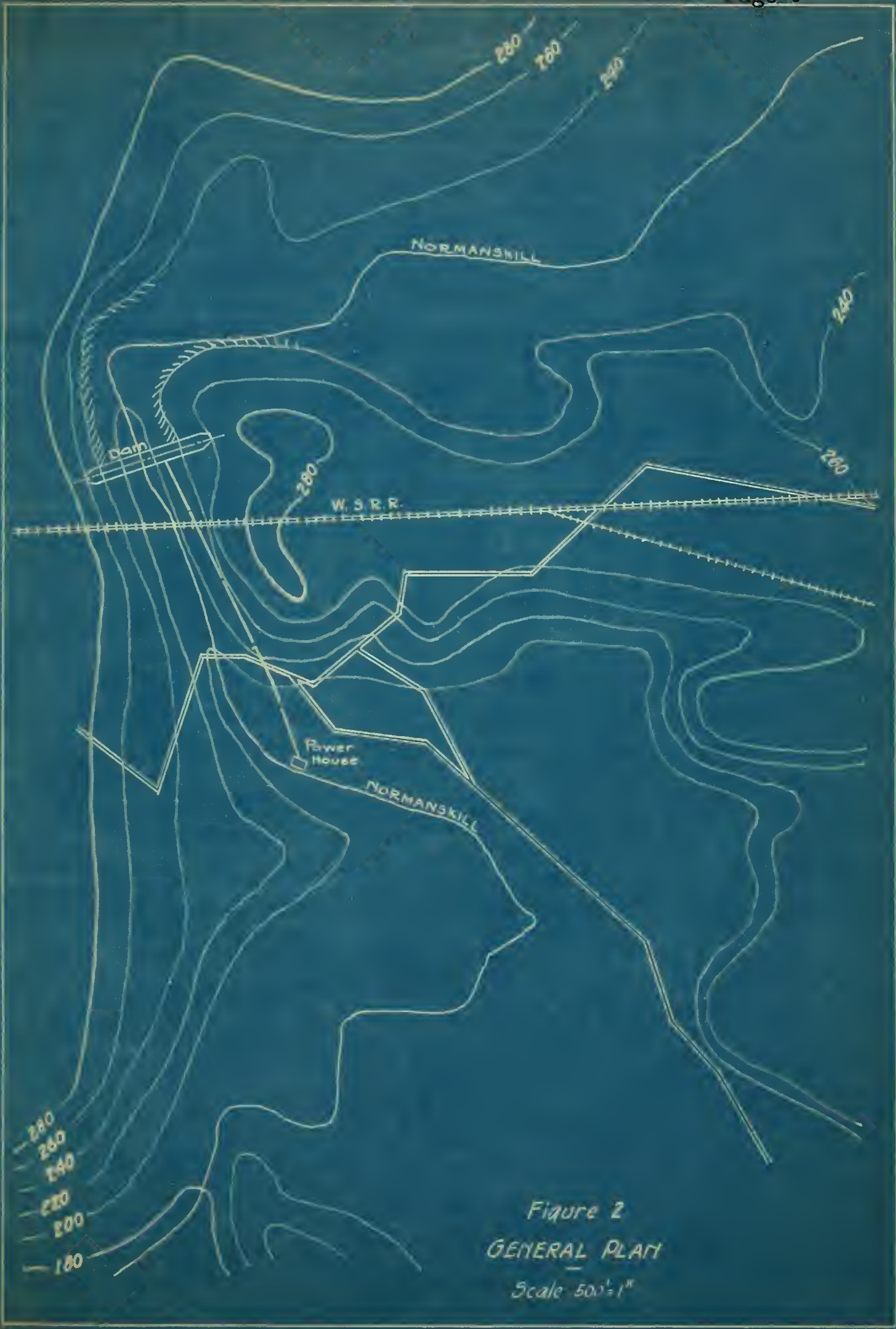


Figure 2
GENERAL PLAN
Scale 500'=1"

HYDRAULIC CALCULATIONS

The average monthly run-off at French's Mills is 183 second feet. The elevation of the bed of the stream at the dam is 220.00 which makes the elevation of the crest 256.00 and of the flashboards 259.00. The low water elevation of the stream at the power house is 187.00. Hence the maximum available head will be 259 - 187 = 72 feet. On this basis, assuming an overall efficiency of 80%, the average maximum horsepower of the stream will be

$$H.P. = \frac{72 \times 183}{11} = 1320$$

The storage reservoir will be considered as extending from elevation 245. to 259 or as 15 feet deep. Assuming the same flow, but with the water at the bottom of the reservoir, i.e. Elevation 245. (which is the condition at the end of the dry period)

$$H.P. = \frac{58 \times 183}{11} = 1060$$

From reference to the run-off curve on Page 12 it will be seen that if a development of 1000 horsepower be made, the average flow of the stream will be sufficient to supply this during seven months of the year, which are also the months during which the power and lighting loads will be the greatest. A greater development than this would result in a shortage of water during more than half the year, and therefore it was decided to develope only 1000 horsepower. This will be done by using four 250 kv.a. alternating current generators. Three of these will be able to take care of the 1000 horsepower and the fourth will be kept for emergency.

During June to October inclusive, the run-off is far short of that necessary for the development of 1000 horsepower. The storage behind the dam is to be used during this period.

Figure 4 shows a topographical map of the storage reservoir. From this it was

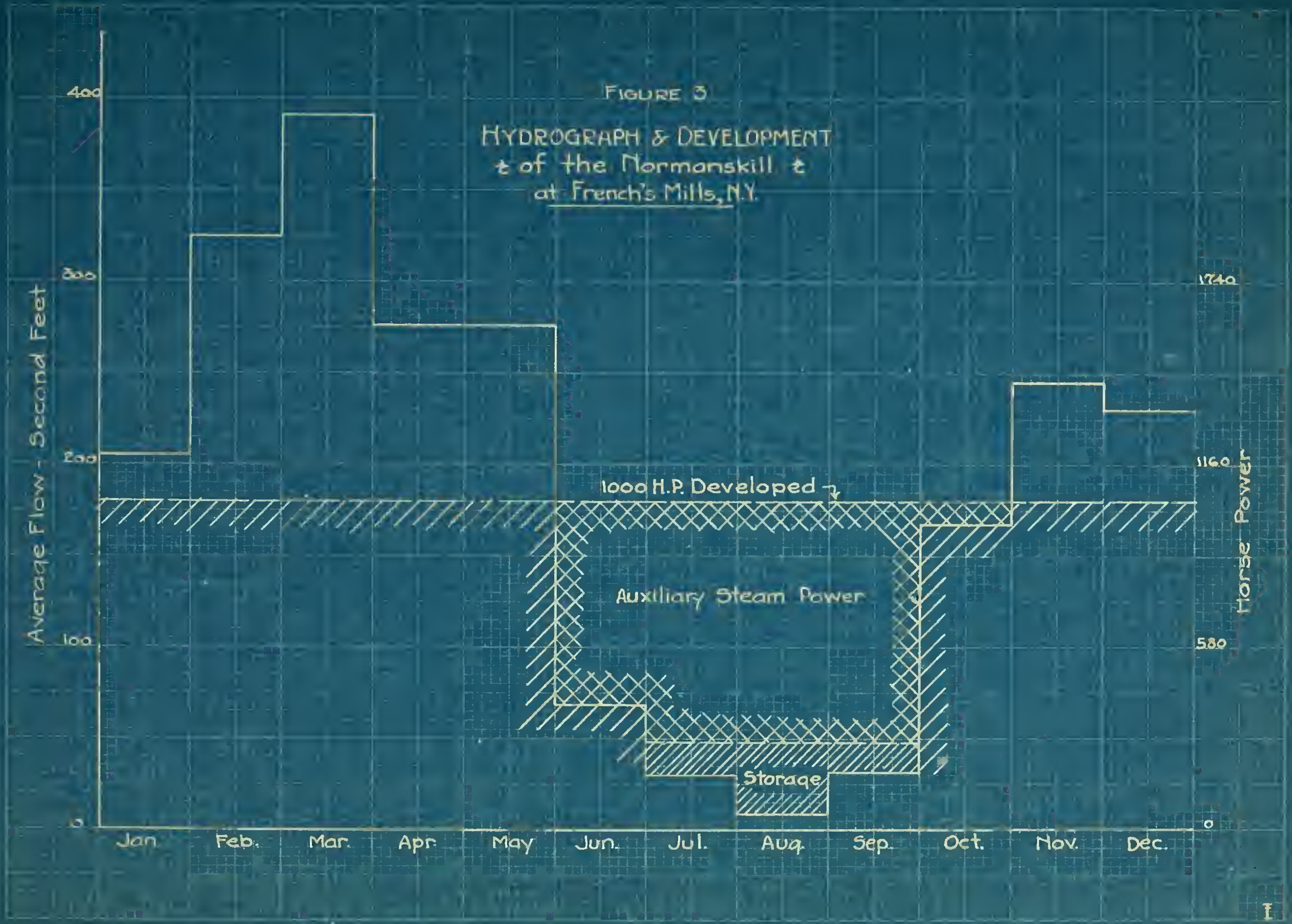


FIGURE 3

HYDROGRAPH & DEVELOPMENT of the Normanskill at French's Mills, N.Y.

found that the area on contour 259 was 448 acres, and on contour 244 was 175 acres. If it be assumed that between these two elevations the slope of the ground is uniform, the volume of storage will be

$$15 \times \frac{448 + 175}{2} = 4680 \text{ acre feet}$$

The minimum flow occurs during August, when the run-off is 8.3 second feet. During July and September the minimum flow is 28 sec.ft. Assuming 24 hour power, to supply the shortage in August will require

$$20 \times 2 \times 30 = 1200 \text{ acre feet.}$$

This leaves

$$4680 - 1200 = 3480 \text{ acre feet}$$

to apply to the deficiency during July, August and September. This will amount to

$$\frac{3480}{3 \times 30} = 38.7 \text{ acre feet per 24 hr. day}$$

$$= \frac{38.7}{2} = 19.3 \text{ second feet.}$$

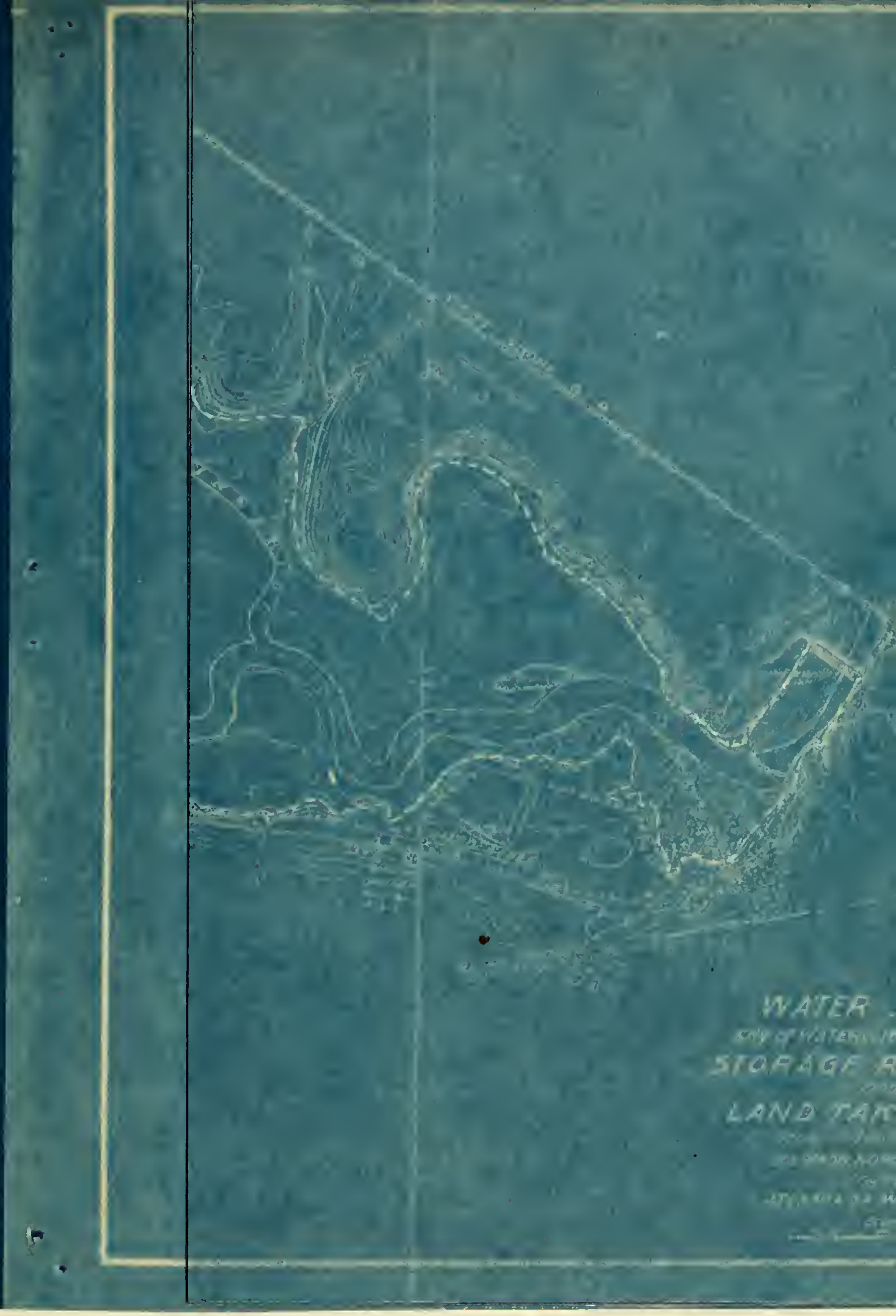
Hence during these three months, the total maximum run-off will be

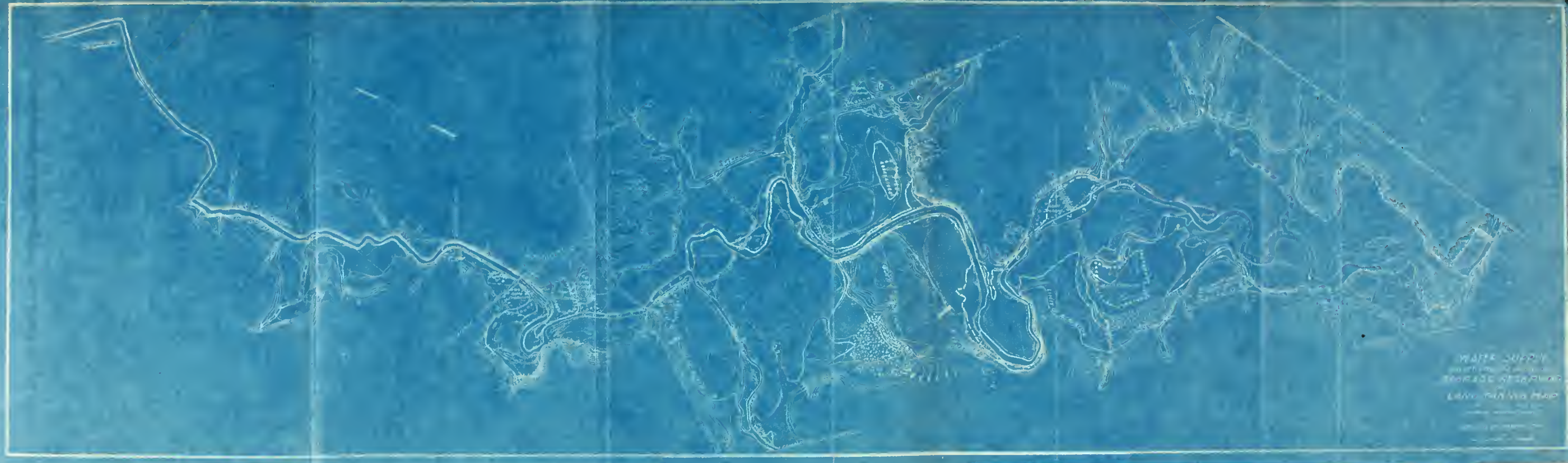
$$\frac{57 \times 47}{11} = 244 \text{ horsepower}$$

This represents the maximum which the storage reservoir may be called upon to supply during the dry season, and is all that can be contracted for unless other means are employed to supply the deficiency.

It is desireable that 1000 horsepower be supplied throughout the year, and to accomplish this, a steam auxiliary plant will be operated in conjunction with the hydraulic. During the dry season the maximum demand which would be made on a steam plant, on the basis of 1000h.p., will be 1000 - 244 = 756 horsepower. The steam plant need not be idle during the winter months, but by keeping it running during the entire year, and operating the two plants together, a much greater amount of power can be contracted for.

Although this thesis will not include


WATER
STORAGE
LAND TA


WATER SUPPLY
STORAGE RESERVOIR
LAND TAKING MAP

the design of this auxiliary steam plant, we understand that there is at present an unused mill building near the site which can be adapted to such a plant, and would advise the joint operation of steam and hydraulic plants.

DESIGN OF DAM

Of the various types of dams which have been designed, there were only two which seemed suitable for this project. In the selection of the type of dam, it was not necessary to do so on the basis of the nature of the foundation, as this is of horizontal rock strata and as good as may be found anywhere. Choice was restricted between a gravity dam and a reinforced concrete structure.

The gravity dam has been employed under a great many different conditions and over a large number of heights, but it is always subject to certain difficulties. From the standpoint of the design, there is always the uncertainty of the impermeability of the base. If water were to gain even a small access to the foundation, it might under unusual flood conditions, become the cause of the failure of the structure by overturning.

For a dam of this size, a solid masonry structure would also be more expensive than one of reinforced concrete. The design of a reinforced dam can be made very accurately and does not involve the uncertain factors of undermining by the action of the water at the foundation. The condition of the dam may also be inspected from time to time when in use. It was therefore decided to make the dam of the reinforced concrete type and to make a complete design in detail.

The water supply dam at present in use at French's Mills is an Ambursen dam, and some data secured from the patentees of this type of construction has formed the basis for the proportioning of the different parts of the structure. A typical cross-section of the dam was drawn up to a large scale and the center of gravity of the structure was found by graphical methods. By combining the

total vertical load with the horizontal thrust of the water, the line of action of the resultant pressure was found. Figure 5 shows a smaller diagram of the typical section and illustrates the method used in finding the base pressures.

Instead of making the buttresses of a uniformly varying thickness from top to bottom, they were made in three sections: 12, 14 and 16 inches thick. The weights of these sections are as follows:

Top Section 241.2 x 150 x 1 = 36,200 lbs.
Mid " 450 x 150 x 1.16 = 78,500 "
Bot. " 535 x 150 x 1.33 =107,000 "

and the total weight of each buttress is 221,700 lbs. Therefore, the weight of buttress per lineal foot of wall, for a distance center to center of buttresses of 18' 0", will be 221,700 / 18 = 12,300 lbs.

The weight of the section of the dam was estimated to be 189.2 x 150 = 28,400 lbs.

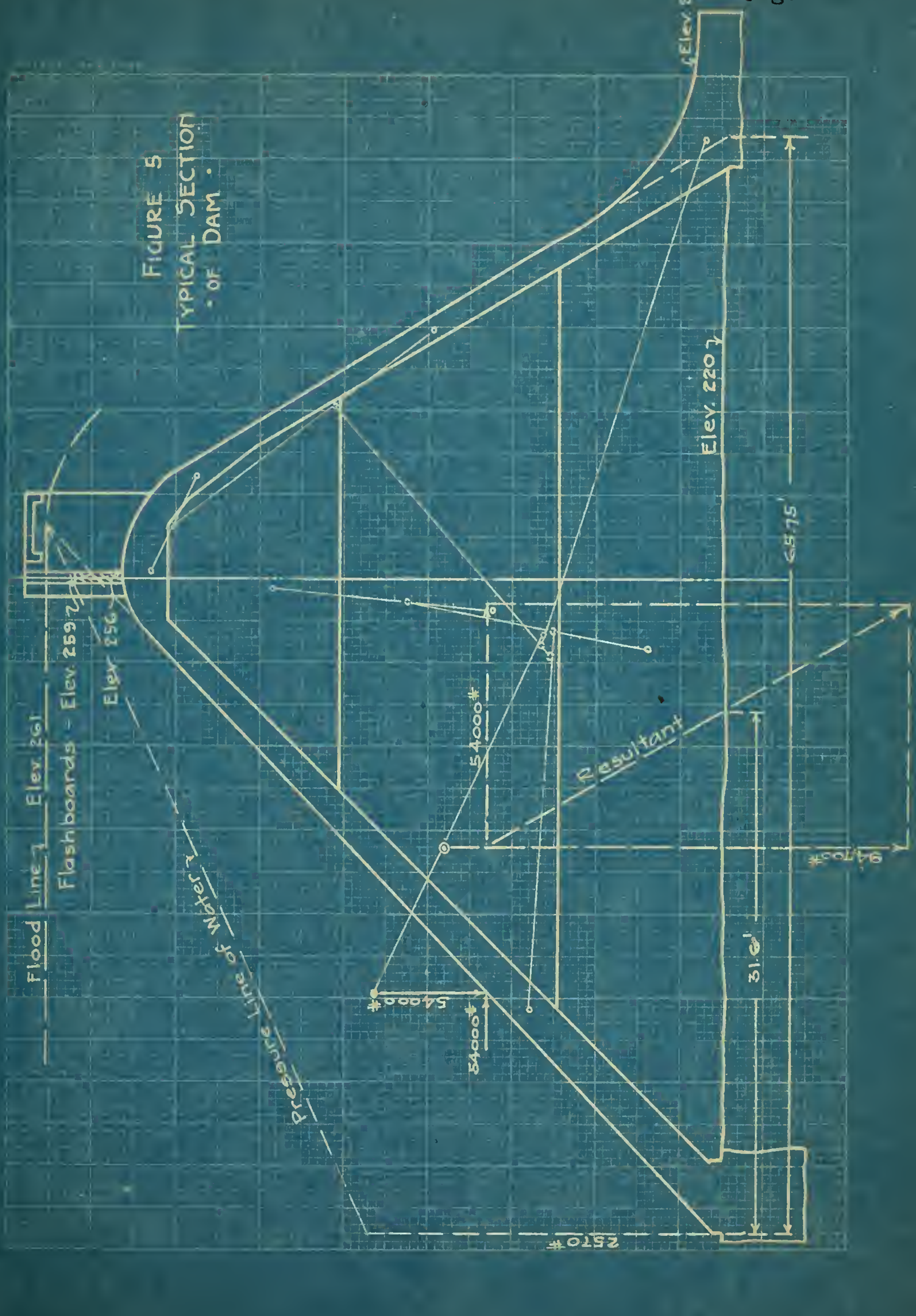


FIGURE 5
TYPICAL SECTION
OF DAM.

Hence the total weight of the structure will be 12,300 + 28,400 = 40,700# per lineal foot.

The dam will have a spillway over practically its entire length of 200 feet. The maximum average flow recorded is 490 second feet. With a velocity of flow of 5 feet per second, the water would stand at a height over the flashboards, assuming a maximum flood flow of 1000 second feet, of

$$\frac{1000}{5 \times 200} = 1 \text{ foot}$$

The flood line will be made to allow the water to rise two feet above the flashboards; i.e. Elevation 261.00. Then the maximum head of water at the heel = 261 - 220 = 41 feet and at the crest 261 - 256 = 5 feet. The unit pressure of the water at the heel will then be

$$41 \times 62.5 = 2570 \text{ lbs.}$$

and at the crest, $5 \times 62.5 = 312.5$ lbs.

The total weight of water on the upstream side of the dam will therefore be

$$\frac{2570 \times 42}{2} = 54{,}000 \text{ lbs.}$$

and the combined vertical forces of water and weight of dam will be

$$54{,}000 + 40{,}700 = 94{,}700 \text{ lbs.}$$

The point of application of this force was found graphically as stated above and it was found that the line of action of the combined vertical forces cut the base of the dam at a point 23.5 feet from the heel.

The horizontal thrust of the water is equal to 54000 lbs. and is applied at a point 14.2 feet above the base, as shown in Figure 5. The horizontal and vertical forces may be resolved into one resultant pressure. The inclination of this resultant is

$$\tan^{-1} \frac{54{,}000}{94{,}700} = 37 \text{ degrees}$$

If "x" represent the distance from the line of action of the vertical force to the point of cutting of the base by the resultant,

$$x = 14.2 \times .57 = 8.08 \text{ feet}$$

Therefore the distance from the heel to the line of action of the resultant is

$$23.5 + 8.08 = 31.6 \text{ feet}$$

The effective length of the base is considered as 65.75 feet, and then the limits of the middle third are $\frac{65.75}{3} = 21.91$ feet. This shows the resultant to cut the base at very close to its center, as is usually the case in dams of this type. The proportions assumed for the various parts of the dam are therefore all right and the section will be made in accordance therewith.

The eccentricity of the point of application of the resultant pressure is

$$32.87 - 31.6 = 1.27 \text{ feet}$$

The pressure at the heel will then be

$$\frac{94,700}{65.75} \left(1 + \frac{6 \times 1.27}{65.75}\right) = 1623 \text{ lbs/ lin.ft.}$$

and at the toe

$$\frac{94,700}{65.75} \left(1 - \frac{6 \times 1.27}{65.75}\right) = 1257 \text{ lbs/ lin.ft.}$$

This shows an almost uniform distribution of stress along the base. It will be assumed that this entire pressure is carried by the buttresses and that none of it is taken by the cut-off wall or apron. The total pressure at the heel of each buttress will then be

$$1623 \times 18 = 29{,}214 \text{ lbs.}$$

and the pressure per square foot with a 16 inch wide base is

$$\frac{29214}{1.33} = 21{,}950 \text{ lbs.}$$

Similarly at the toe, the pressure is

$$\frac{1257 \times 18}{1.33} = 17{,}012 \text{ lbs./sq.ft.}$$

Both of these values are well within safe limits against crushing.

For the purpose of designing the decks on the upstream side of the dam, they are divided into a number of parts as shown on Plate III, and each of these is designed as a simple beam slab for the maximum water pressure on it and the proper amount of steel reinforcement found. The buttresses will be

placed 18' 0" center to center and will be provided with an enlarged end to carry the deck slabs as shown in Figure 6. The bottom section of the deck is 14' 0" wide on

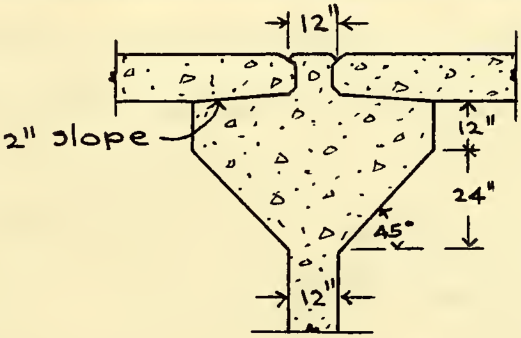


Figure 6

the under side and is poured monolithic. The maximum pressure on this section is 2570 lbs. per square foot. The length of the span is 12' 8". Weight of the deck = 2.5 x 150 = 375 lbs.

$$B.M. = \frac{12}{8} Wl^2 = \frac{2975 \times 160 \times 12}{8} = 715{,}000$$

inch lbs.

$$M = Rbd^2 \qquad d = \sqrt{\frac{715000}{12 \times 98}} = 25 \text{ inches}$$

The depth assumed in the preliminary layout was 28 inches effective and this will be kept.

The values used for allowable stress in steel and concrete are: $f_s = 15000$ and $f_c = 600$ lbs. per square inch. Therefore, from Figure 18 of Turneaure and Maurer, the percentage of steel to be used will be 3/4 of one percent. For the bottom section the area of steel required will be

.0075 x 28 x 12 = 2.52 sq.in. per foot of width. 1-1/4 inch round rods will be used, and spaced 5-1/2 inches centers. 31 rods will be required. The total shear = 2570 x 6.3 = 16200 lbs. Therefore the unit shear is

$$u = \frac{16200}{2.18 \times 3.92 \times .84 \times 28} = 80 \text{ lbs.}$$

This is well within safe limits, but in placing the steel, every third bar will be bent up at the supports.

The second section of the deck is 10' 0" wide and has a maximum pressure of 1890 lbs. and a length of span of 12' 10". The weight of the deck = 2.25 x 150 = 338 lbs. Hence the total loading will be 1890 + 338 = 2228

lbs. per square foot.

$$B.M. = \frac{2228 \times 12 \times 164}{8} = 550,000 \text{ inch lbs.}$$

$$d = \sqrt{\frac{550,000}{12 \times 98}} = 21.6 \text{ inches}$$

The depth will be made 25 inches as in the preliminary design. The steel required is

$$.0075 \times 25 \times 12 = 2.25 \text{ sq. inches.}$$

Use 1" round rods, 4" centers, 30 required. Every third rod will be turned up as in the previous case.

In the third section the maximum pressure is 1450 lbs. and the dead weight of the concrete 300 lbs, making a total load of 1750 lbs. per square foot. The length of the span is 12' 10".

$$B.M. = \frac{1750 \times 12 \times 164}{8} = 430,000 \text{ inch lbs.}$$

$$d = \sqrt{\frac{430,000}{12 \times 98}} = 19.25 \text{ inches}$$

The depth at this point will be made 21 inches. The steel required = .0075 x 21 x 12 = 1.89 square inches. 1" round rods will be used,

placed 5" centers. 19 will be required.

The fourth section is 10' 0" wide and the total pressure against it is 1343 lbs. per square foot. The length of span is 13' 0".

$$B.M. = \frac{1343 \times 169 \times 12}{8} = 340{,}000 \text{ inch lbs.}$$

$$d = \sqrt{\frac{340{,}000}{12 \times 98}} = 17"$$

The depth will be made 18".

Steel required = .0075 x 18 x 12 = 1.62 sq. inches. Use 1" round rods on 5-1/2" centers. 22 rods will be required.

The fifth section is 5' 0" wide and the maximum pressure on it is 875 lbs. The span is 13' 0".

$$B.M. = \frac{875 \times 12 \times 169}{8} = 222{,}000 \text{ inch lbs.}$$

$$d = \sqrt{\frac{222{,}000}{12 \times 98}} = 13.75 \text{ inches}$$

The depth will be made 15 inches.

Steel required = .0075 x 15 x 12 = 1.35 sq.in. Use 1" round rods on 7" centers. 8 are required.

According to the preliminary design, the minimum depth of the arch at the crest of the dam is 18 inches, and the maximum pressure of water and dead weight combined is 675 lbs per square foot. The width of this section is about 9' and the span is 13' 0". On the basis of the assumed depth, the area of steel required is .0075 x 18 x 12 = 1.62 sq. inches. 1" round rods will be used, spaced 6" centers. 18 rods will be required.

On the downstream face, the water pressure will be the same over its entire area. The pressure assumed will be that due to a five foot head of water which will give

$$5 \times 62.5 = 312.5 \text{ lbs. per sq. ft.}$$

The weight of the deck itself will be

$$1.25 \times 150 = 188 \text{ lbs.}$$

based on a depth of 15 inches. Then, thee

$$B.M. = \frac{501 \times 169 \times 12}{8} = 127{,}000 \text{ inch lbs.}$$

$$d = \sqrt{\frac{127{,}000}{12 \times 98}} = 10.5 \text{ inches.}$$

The effective depth of 13" assumed is therefore well on the safe side. The area of steel required is .0075 x 12 x 13 = 1.17 sq. inches. Use 1" round rods spaced 8" centers. 56 rods will be required.

Struts are to be placed horizontally between the buttresses to give these greater stiffness. The empirical rule for these is to place them at vertical distances of 24 times the thickness of the buttress and horizontally about 10 thicknesses apart. These struts will be reinforced to carry their own dead weight as beams and also will have some steel in their upper faces. They will be placed just below the construction joints; two at the bottom joint and one at the upper as shown on the cross-section of the dam. The struts will be made 14" x 18" and will be reinforced with 5 - 1" x 20' 0" rods, two in the upper surface and three in the lower.

The horizontal joints between the different sections of the buttresses will be made as shown on Plate III in order to provide greater resistence to sliding. The foundation for the buttresses is also to be made rough so as to offer good resistence as well as to provide a satisfactory bond. In excavating for the foundation and for the cut-off trench on the upstream side, no dynamiting is to be done, and care should be exercised to prevent the opening of any seams in the rock.

A walkway is to be provided above the dam by extending the buttresses up to Elev. 263.00. The walk will be made 4' 0" wide and will be provided with a standard pipe handrail. A dead load of 50 lbs. per square foot is assumed over the entire walk. With a 5" slab, the weight of concrete will be

$$\frac{5 \times 48}{144} \times 150 = 249 \text{ lbs. per lin. ft.}$$

The total load per foot will then be 300 lbs.

$$B.M. = \frac{12}{12} WL^2 = 300 \times 18 \times 18 = 97{,}200 \text{ inch lb.}$$

$$d = \sqrt{\frac{46{,}600}{98 \times 24}} = 4.4 \text{ inches}$$

The slab will be made 6 inches deep with a beam on each side of depth 10 inches. With 1% steel, the area required will be

$$(48 \times 6 + 4 \times 8) \times .01 = 3.2 \text{ sq.inches}$$

Use 3/4" square twisted rods, 2" centers.

The plan and downstream elevation of the dam are shown on Plate II. There will be thirteen hollow sections as shown, and at the ends the section will be made solid but of the same proportions as in the typical section.

DESIGN OF PIPE LINE AND INTAKE

The water is to be carried from the dam to the power house through a riveted steel pipe line. The length of the pipe line is 1450 feet and its alignment is as shown on Plate I, which is a general map of the development. On account of the lack of data concerning the nature of the country between the dam and the power house, the direction of the pipe line was made practically the same as that of the actual penstock now in use on the Municipal Water Supply for the city of Watervelist, N.Y.

From the hydraulic calculations, the average flow Q has already been found to be 183 second feet, and the maximum available head H = 72 feet. Since the head is not large, it is convenient to assume a small velocity of the water. Taking V = 8 feet per second the diamter necessary is

$$D = \sqrt{\frac{Q}{.785V}} = \sqrt{\frac{183}{.785 \times 8}} = 5.4 \text{ feet}$$

A 5-foot pipe line will be used, which gives a velocity

$$V = \frac{Q}{.785\ D^2} = \frac{183}{.785 \times 25} = 9.3 \text{ sec. feet.}$$

This velocity gives a friction head of

$$H_f = f\ \frac{L}{D}\ \frac{V^2}{2g} = 4.86 \text{ feet}$$

Therefore the maximum useful head is reduced to $72 - 4.86 = 67.14$ feet.

The penstock will be of riveted steel. The thickness of the steel required is calculated from the formula:

$$t = \frac{(p + p')\ r}{7000} \text{ inches}$$

where $p = .433h$, and p' = the pressure allowed for water hammer. From the specifications of the New England Water Works Assn., for a 60 inch pipe, $p' = 70$ lbs/sq.in.

For the first 480 feet of the pipe line,

$H = 42$. Hence $p = .433 \times 42 = 18.2$

Then $t = \dfrac{(18.2 + 70)\ 30}{7000} = .378$ in. (3/8")

For the maximum head of 72 feet, $p = 31.2$

and $t = \dfrac{(31.2 + 70)\ 30}{7000} = .433$ in. (7/16")

Therefore, for the first 480 feet, 3/8 inch steel plate will be used and for the remainder of the line where more abrupt changes of grade occur, 7/16 inch plate will be used for the penstock.

For the first 480 feet, the stress in lbs. per square inch on the rivets of the pipe will be $(18.2 + 70)\ 30 = 2640$ lbs and for one foot, the stress is $2640 \times 12 =$ 31,600 lbs. 7/8" rivets will be used. The allowed single shear for these is 9000 lbs., or 5410 lbs. per rivet. Therefore, the number of rivets required per foot of pipe is

$$\frac{31,600}{5410} = 6$$

The rivets will be put in a double row and staggered as shown on the details of the pipe on Plate VI. For the remainder of the line, the stress per foot is $(31.2 + 70)\ 30 \times 12 =$ 36,400 lbs.

and $\frac{36,400}{5410}$ = 7 rivets required.

Four expansion joints will be used. The location of the expansion joints and their details are shown on Plate V. which also shows a profile of the penstock. The expansion joints are of the diaphragm type designed by W. J. Walsh, and which have been used on many large developments and which have given very satisfactory results. Both the profile of the ground and the approximate alignment of the penstock were determined from drawings of the Water Supply of Waterveliet, N. Y. by Solomon, Norcross and Keis, Engineers.

From the profile it is seen that along the greater part of its length, the penstock is covered with earth. Therefore, for the first half of the line, anchorages will be used only where the penstock changes in direction or grade. For the remainder of the penstock, which then runs in a straight line, concrete saddles will be used every 50 feet.

At a distance of 480 feet from the dam, the penstock will be supported for a length of 120 feet by 6 concrete piers, spaced 20 feet centers. Between piers, the penstock will rest on I-beams which will support the load of $5^2 \frac{\pi}{4} \times 20 \times 62.4 = 24,500$ lbs. 12" x 50 lb. I-beams will support 27,500 lbs. on a 20 foot span, and therefore this size of beam will be used.

At the end of the pipe line which it is to enter the power house, there will be four distributors, for the four generating units. Only three of these, however, will run at one time so that the water flowing in one distributor is $\frac{183}{3} = 61$ second feet. The velocity of the water in the distributors will be made the same as that in the main line in order to prevent any losses due to an abrupt change in velocity. Therefore, the diameter of the distributors will need be

$$D = \sqrt{\frac{61}{.785 \times 7.3}} = 2.87 \text{ ft.}$$

Instead of leaving the penstock perpendicularly, the distributors will make an angle of 30 desgrees with it. In this way, the head lost in the bends will be greatly reduced.

A butterfly valve is to be installed on each distributor making it possible to shut off the water from any turbine independently of the others. It is expected that the load will remain fairly constant, and the three turbines will operate continuously. The amount of water required per unit of time will therefore be practically constant. There will consequently be no surges in the pipe line, and no surge tank is required. Furthermore, the line is so short that any small surges due to the sudden closing of the gate to one unit will cause no damage to the pipe.

The penstock is to extend through the dam to form the intake, and the entire supply of water will be controlled by means of a gate valve placed within the dam. This is

so arranged that it may readily be operated from the walk inside the dam. Racks are provided across the opening to keep trash and large material from getting into the wheels. To prevent a large loss in head at the entrance to the penstock, this will be enlarged at the opening. Assuming a velocity through the racks of two feet per second, the required diameter of the opening is

$$D = \sqrt{\frac{183}{.785 \times 2}} = \sqrt{\frac{183}{1.57}} = 10.5 \text{ ft.}$$

D was made 8' 0" which gives a velocity of

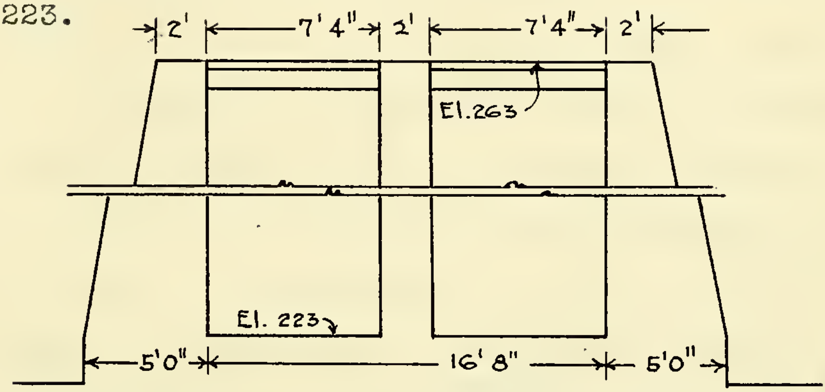
$$V = \frac{183}{.785 \times 64} = 3.62 \text{ ft. per sec.}$$

In order to reduce eddies at the entrance, this has been rounded at the edges. The details of the intake are shown on Plate IV. The trash racks are supported on a concrete curb on all four sides, and by means of a 15" x 42 lb. I-beam across the center. The racks are made of the standard type: that is, of 1/4" x 3" flat rolled steel bars placed

1-1/2" centers. The bars are separated by 3/4" pipe sleeves and bolted together with 5/8" bolts at the two ends and at the center. They are made in eight sections, each 12' 0" x 3' 8".

In order to make it possible to shut off the water from the intake in order to make repairs, etc. it was found necessary to build a small forebay which could be closed up with stop logs. This forebay will consist of two walls extending up to the elevation of the walk above the dam, and out to the heel. The walls will be braced by means of struts at the upper end, and walks will be provided across them to fascilitate placing the stop logs and raking the trash racks. The end elevation of the forebay is shown below. The maximum head acting on the walls when the interior of the forebay is empty will be 261 - 223 = 38 ft. This force can be considered as being applied at a point one-third

up from the base or at 12.6 ft. above Elev. 223.



The average unit pressure at the outer edge of the wall is $\frac{62.5 \times 38}{2} = 1190$ lbs.

The total pressure on one foot width of wall is 1190 x 38 = 45,300 lbs. If the wall is assumed to act as a simple beam, the resultant at the upper end is .33 x 45,300 = 13900# and at the lower end is .66 x 45,300 = 31400#

The Maximum B.M. = 31400 x 12.6 x 12 = 4,750,000 inch lbs.

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{4,750,000}{98 \times 12}} = 63.5 \text{ inches}$$

The depth at the base will be made 5' 0"

The section will be reinforced with 1% of steel. Hence the steel required will be

.01 x 60 x 12 = 7.2 sq. inches.

1-1/4" sq. twisted rods will be used, spaced 2-1/2" centers. These will be held in position with 3/4" spacing rods, placed 3ft. centers. The face of the dam will take one reaction of the walls. The reaction at the top will be taken by struts placed across the opening. Considering the wall made up of four sections vertically, the upper reaction of the longest section will be 13,900 x 10 = 139,000 lbs. For the fourth and shortest section, the reaction is 6670 lbs. This section is above the crest of the dam and here the section is solid and will take care of the thrust at this point. At the center of each of the other three sections, struts will be provided to take the thrust. In each case a walk will be placed above the strut.

The maximum thrust is 139,000 lbs.

$P = f_cA(1 + (n-1)p)$

$139{,}000 = 650\ A\ (1 + 14 \times .02)$

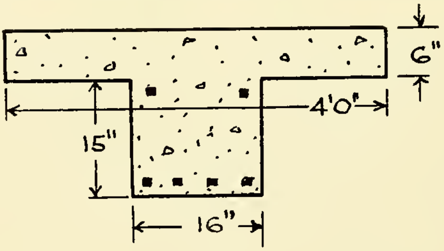
Area = 139 square inches.

Steel area = .02 x 144 = 2.88 sq. inches.

4 - 7/8" sq.twisted rods will be required.

Outside dimensions of struts will be 16" sq.

When a walk is placed above the strut as shown in the figure, the strut will act as a simple beam, and carry its own weight plus a suniformly distributed load of 50 lbs. per square foot.



The length of span is 18' 0" and the bending moment $M = \frac{650 \times 18 \times 18 \times 12}{8} = 31,600$ in.lb.

$$A_s = \frac{M}{f_s jd} = \frac{31,600}{16,000 \times .9 \times 15.5} = 1.41 \text{ sq.in.}$$

This will require two additional 7/8" sq. rods

As the span of 18 feet is too great for stop logs, a pier will be placed in the center. The maximum load on this pier will be 40,700 lbs.

B.M. = 40,700 x 13 x 12 = 6,350,000 inch lbs.

$$\text{Then} \quad d = \sqrt{\frac{6,350,000}{98 \times 12 \times 2}} = 52 \text{ inches}$$

The maximum depth will be made 7'0"   Using 1% steel, the area required will be .01 x 82 x 24 = 19.68 sq.in. Use 9-1 1/2" square twisted rods.

Complete details of the forebay are shown on Plate V.

DESIGN OF POWER HOUSE

General

For the design of the power house substructure, the fundamental information necessary was the spacing and weights of the several units, their overall dimensions, and the probable arrangement of the various electrical and hydraulic equipment of the plant, in order that the general dimensions of the main generator room might be found, together with the probable pressures on the foundation.

Elsewhere, the available power has been found to be about 750 K.W. The load conditions of a day power and lighting load and a night lighting load, both street and residence, made it seem expedient to install four units of 250 K.W. capacity; three to take care of this varying load and the fourth to serve as a spare unit. The power is to be generated at 2300 volts. The lighting load demands that this be generated at 60 cycles to obviate lamp flicker. For economy of transmission,

the three-phase system will be used.

Since the total power, 750 K.W., transmitted at 2300 volts would require a transmission line capable of carrying a current of 750,000/2300 = 325 amperes, approximately, the conductor cost would be excessive; a set of transformers (three-phase) will therefore be used to raise the transmission voltage to 6600, thus cutting the current to about one-third its former value.

It was possible to pick out from the various trade catalogues a turbine which was rated at 340 H.P. 514 r.p.m, but lack of interest on the part of the manufacturers made it impossible to obtain the general dimensions of this turbine. It was possible, however, to secure the over-all dimensions of a slow-speed alternator of the requisite size, and the general dimensions of a turbine to connect to this machine have been calculated.

General Design of Turbine

The data given for the above-mentioned alternator was as follows:

Manufacturer - General Electric Co.
Type - T.R.C. 3-Phase
Poles - 44
Rating - 240 kv.a.
R.P.M. - 164
Voltage - 2300
Cycles - 60

The formula for the "specific speed" of a turbine, as given by Gelpke and Van Cleve in their book on Hydraulic Turbines, is

$$K_n = n^2 \frac{P}{H^{2.5}}$$

where K_n is the specific speed, n is the number of r.p.m., P is the horsepower, and H is the average head. From the alternator data, we have that n = 164, P = 320, P has been previously determined as 64 feet, Hence,

$$K_n = \frac{(164)^2\ (320)}{(64)^{2.5}} = 262$$

The specific speed, or the r.p.m. of a homologous wheel of such a diameter that it would develop one h.p. under a one foot head, is

given in the same source as

$$N_s = \frac{n\ P^{.5}}{H^{2.5}} = \sqrt{K_n}$$

Hence $N_s = \sqrt{262} = 16.2$

This figure places the turbine under the head of a "Case VI" turbine. The theoretical values of the dimensions of such a turbine are as follows:

(1) B = Runner height = $.125\ D$

(2) Q_1 = Discharge under unit head = $.441\ D^2$

(3) n_1 = R.P.M. " " " = $.83\ D$

(4) $P_1 = \frac{Q_1}{11}$ = power " " " = $.040\ D^2$

D, in all cases, is the runner diameter of the turbine under discussion. The power under one-foot head is $P_1 = \frac{P}{H^{1.5}}$, where P is the total power, H is the average head, hence,

$$P_1 = 320/64^{1.5} = .625$$

but $.625 = .040\ D^2$ (Equation 4)

Then $D = \sqrt{\frac{.625}{.040}} = 3.95$ feet

D = 3.95 x 12 = 47.4" = 48" turbine runner.

$B = .125 \times 48 = 6''$ (Equation 1)

$Q = Q_1\sqrt{H} = .441\ D^2\sqrt{64} = 56.4$ sec. feet

E = Efficiency, assumed to be 83% at 3/4 load.

$$(5)\quad H.P. = \frac{Q\ W\ H\ E}{550}$$

Where Q is the total quantity of water, W is the weight per cubic foot of water, H is the average head, E is the efficiency. Using Q as 61 second feet, the h.p. input to the alternator is

$$H.P. = \frac{61 \times 62.5 \times 64 \times .83}{550} = 368$$

Assuming an electrical efficiency of 91%, including alternator and transformer efficiency, $H.P. = 368 \times .91 = 334$

The last equation (5) gives a check on the design, and such a turbine will be used. The diameter at the bottom of the runner, and therefore of the upper end of the draft tube will be .7 D as outlined on page 163 of Gelpke and Van Cleve. $.7 \times 4 = 2.8$ feet

Allowing for the thickness of the crown and for clearance, this diameter may be taken as

2.9 feet, the same as the diameter of the penstock. With his in mind, the cross-section of the water channel from the end of the penstock to the beginning of the draft tube will be made of such dimensions that the velocity of the water will remain constant throughout its flow between these two points.

Design of Scroll Case

According to Mr. A. G. Hillberg, in the Engineering News of Oct. 2, 1915, the velocity of the water at the entrance of the scroll case is $V = C\sqrt{2gh_o}$ where V is the entrance velocity, $C = .15$, $g = 32.2$, h_o is the operating head $= h_a - \frac{\sqrt{h_a}}{3}$, and h_a is the average head.

$$h_o = 64 - \frac{\sqrt{64}}{3} = 61.3$$

$$V = .15\sqrt{2 \times 32.2 \times 61.3} = 9.36\ '/\text{sec.}$$

This figure corresponds to the velocity of flow in the penstock, 9.3 ft. per sec. very closely, and the latter value will be used.

The center line of the section will be kept at all times in the same horizontal plane

as the center line of the runner opening. From the bottom and top of the guide ring, the sides of the scroll case will slope at an angle of 45 degrees to the horizontal axis.

The turbines will be set at an angle of 240 degrees with the transverse axis; that is, the scroll case will begin at an angle of 240 degrees from the transverse axis of the turbine, measuring from the right hand in a counter-clockwise direction. Dividing the turbine section into twelve equal parts, each part equals 30 degrees, so that on thee transverse axis, at 180 degrees, the amount of water to be allowed for is not Q, but since 60 degrees or two of the equal sections have been passed in coming from 240 degrees, 5Q/6 . At 0 degrees, eight sections have been compassed and the area must allow for Q/3.

In the preliminary design, setting the turbine at an angle of 180 degrees was tried, and all sections figured. The resulting out-

line, however, was impractical at the entrance section, and was abandoned. The latter section, however, was the only area which it was found necessary to change, so that the sections for the 180 degree setting will be used, and that for the entrance section corrected. Assuming this setting, the amount of water to be allowed for is Q and $\frac{Q}{2}$ at 180 degrees from the entrance.

The section S_o, carrying Q, was first found by laying off 1.5 feet on each side of a center line and drawing horizontal lines through these two points to meet the 45 degree lines from the upper and lower guide vane ring edge. The area between the 45 degree lines was then computed. The area of a 2.9 ft. circle (the distributor pipe section) is 6.6 sq.ft. This amount - the area between the 45 degree lines, gives the area to be taken care of by a rectangular section. This latter area, divided by three gives the width

of the required section. By taking a definite radius to lay off the rounded corners, the loss of area due to this factor may be found and enough added to the width to give the required area.

For the method used in designing another section let us take that required to carry say Q/2, for an example. Obviously, since $A = \frac{Q}{V}$, and V is constant, the required area must be half that already designed. As has been stated, it is desired to keep all sections symmetrical with the center line insofar as vertical distances go. Therefore, with this restriction it is probably the simplest method to treat both dimensions the same way. If we then divide the dimensions of the different elements of S_o by $\sqrt{2}$, the area bounded by this new set of dimensions should give $S_6 = .5S_o$, since $\frac{A}{\sqrt{2}} \times \frac{B}{\sqrt{2}} = \frac{AB}{2}$ where A and B are the dimensions of the rectangular section of S_o. But $\frac{1}{2} = \frac{6}{12}$ or $\sqrt{2} = \frac{\sqrt{6}}{\sqrt{12}}$. In other words, for any

section, the dimensions of S_0 multiplied by the square root of the amount of water to be carried gives the proper dimensions of that section, or

$$S_n = \frac{A\sqrt{n}}{\sqrt{12}} \times \frac{B\sqrt{n}}{\sqrt{12}}$$

That section of the area between the 45 degree lines cannot, however, be reduced in the same proportion as the rectangular area since there must be some allowance made for skin friction etc.; a usual method is to add to each successive area an additional percent of that area, thus, second area - 1% increase; third area - 2%; nth area - (n-1)%. In this case it was found that by decreasing the width (from the turbine outward) of the trapezoidal section by the same ratio as the dimensions of the rectangular section is increased, this increase for friction losses is automatically taken care of.

Sample Calculations of Areas S_o and S_6

For S_o, the constants are: a = 3 feet b = 1.67 ft. c = 1.25 ft. Hence the area of the rectangular section = ab = 3 x 1.67 = 5.01 square feet. The area of the trapezoidal section = $\frac{3+.5}{2}$ x 1.25, where $\frac{3+.5}{2}$ is the average length of figure. The area of the trapezoid is 2.19 square feet. The total area will then be 5.01 + 2.19 = 7.20 sq. ft. The outer outline of the section contains two quarter circles of one foot radius, making the total area included between these curves and a line through their centers $\frac{3.14}{2} = 1.57$ sq. ft. The rectangular area containing the circular section is 2 ft. The loss in area due to curvature is therefore 2 - 1.57 = 0.43 sq. ft. The curvature on the inside edges of the section can not be calculated but will be assumed to be about .2 ft. The net area is then 7.20 - (.2 + .43) = 6.57 sq.ft.

The required area is 61/9.3 = 6.56 sq.ft.

For S_o, the required area = $.5S_o$ = 3.28 sq. ft. a = 2.1 ft. b = 1.2 ft. c = .88 ft.

ab = 2.1 x 1.2 = 2.52 sq. ft.

$\frac{2.1 + .5}{2}$ x .88 = 1.15 sq. ft.

Total 3.67 sq. ft.

Subtracting .20 for curvature

Net area = 3.47 sq. ft.

This allows 6% of the required area for friction loss, etc.

The following table gives the values of the different areas, being the straight line areas corrected for curvature of corners. The "required area" is that determined from the equations A = Q/V

Sec.	Q	a in.	b in,	c in.	Req. Area	Act. Area
0	12/12	36.00	20.00	15.00	6.56	6.56
1	11/12	34.63	19.2	14.4	6.03	6.09
2	5/6	33.00	18.3	13.7	5.47	5.57
3	3/4	31.20	17.3	13.0	4.92	5.06
4	2/3	29.4	16.37	12.24	4.39	4.55
5	7/12	27.4	15.25	11.64	3.80	3.99
6	1/2	25.4	14.12	10.6	3.28	3.48
7	5/12	23.2	12.90	9.7	2.73	2.91
8	1/3	20.00	11.54	8.48	2.19	2.35
9	1/4	18.00	10.00	7.50	1.64	1.80
10	1/6	14.70	8.16	6.00	1.09	1.19
11	1/12	11.4	5.8	4.34	0.55	0.61
12	0	0	0	0	0	0

As previously stated, these areas are for a theoretical setting of 180 degrees. To apply them to a 240 degree setting it is only necessary to make $S_o = S_2$: that is, merely revolve the axis of the unit through 60 degrees, in a counter-clockwise direction. The dimension "b" is now plotted on the turbine section, measuring radially from a circle drawn concentric with the turbine, but with a radius 8 inches greater. This circle represents the outer edge of the guide vane ring. When these points are connected by a continuous curve, the outer boundary of the scroll case is found. The nose of the scroll case is now sketched in and both sides connected to the intake pipe.

An investigation of this latter section showed that the width between S_2 and S_o was considerably greater than that designated in the table. These sections were therefore redesigned. Finally, the shape of the intake

from S_o to the penstock was sectioned to gradually change from the scroll case section to a circular one. The several sections are shown in detail on Plate VII. The pier nose is to be of cast iron of the special design shown on the above drawing.

Design of Draft Tube

The draft tube design presents no great difficulties. The velocity at the head of the draft tube was fixed by the turbine design as 9.3 second feet with a circular area of 6.6 square feet, or a diameter of 2.9 feet. The velocity at exit was assumed to be 4 feet per second and this gave an area of 61/4 = 15.25 sq. ft. This area corresponds to a circle of 4.52 feet diameter. This would entail no great difference in the expense of excavation over a shallower section and will therefore be used.

To determine the longitudinal section of the draft tube, it was first decided to

have the elevation of the guide vane ring 14 feet above the lowest elevation of the tail water. Adding to this 2 feet of water above the top of the draft tube and 2.26 feet to the center of the end of the draft tube gives a total height of 18.26 feet. Since the height of 14 feet was assumed, and need not necessarily be any particular value (except that it must be less than 33 feet) this was changed to 14.24, making a total difference in elevation of 18.5 feet between the runner and the center of the draft tube.

The preliminary sketch of the plant layout showed that for economy of space, 24 ft. was the most that could be allowed for horizontal length of the draft tube.

Probably the simplest form of curve for the tube is a section of a parabola, and this was chosen. The equation of a parabola is $y^2 = 2ax$ In this particular case two points are located on the proposed parabola, suppos-

ing the curve to start at the origin of coördinates. These points are the top of the draft tube, (0,0) and the bottom, (24,-18.5) Placing these two values in the equation, we have

$$342 = 2a \times 24$$

$$a = 342/48 = 7.15$$

Hence, $y^2 = 14.3\ x$

Using this equation, and assuming values for "x", the following table was compiled.

x	y	x	y	x	y
1	3.78	9	11.35	17	15.60
2	5.35	10	12.00	18	16.10
3	6.55	11	12.55	19	16.50
4	7.56	12	13.10	20	16.95
5	8.45	13	13.65	21	17.4
6	9.26	14	14.20	22	17.8
7	10.00	15	14.65	23	18.2
8	10.70	16	15.15	24	18.5

These values were plotted and the parabola drawn. As the curve was almost tangent at the lower limit, it was decided to leave

it as it was. The rectified length of the parabola was 32 feet, and for purposes of section design was divided into a number of equal parts by lines drawn at right angles to tangents at these equi-distant points. On this page the values of the upper and lower end areas are given as 6.6 and 15.25 feet respectively. Their difference is 8.65. The increase in area for each section is 8.65/16 x (n-1), where "n" is the number of the section taken. Table B gives the required areas and the corresponding diameters.

TABLE B

Sec.	Area	Diam.	Sec.	Area	Diam.
1	6.6	2.9	10	11.46	3.84
2	7.14	3.02	11	12.00	3.9
3	7.68	3.10	12	12.54	4.0
4	8.22	3.24	13	13.07	4.07
5	8.76	3.34	14	13.62	4.17
6	9.30	3.44	15	14.15	4.25
7	9.84	3.54	16	14.70	4.33
8	10.38	3.68	17	15.25	4.42
9	10.92	3.74			

Circles were drawn with these diameters and with the section points as their centers.

The curve tangent to the several circles at the section lines gave the outline of the draft tube.

General Layout

Before it is possible to determine the actual dimensions of the sub-structure it will be necessary to make a general selection of the auxiliary apparatus to be used, in order that space may be allowed for them. These having been determined and an economical lay-out devised, the floor space necessary, and therefore the substructure dimensions may be ascertained.

The alternators, as already described, are to generate 2300 volts, and this will be stepped up by means of transformers to 6600 volts. For this purpose, a three-phase transformer will be used with each unit, since the space required is less than for three single phase transformers. The general dimensions of such a transformer are 3 x 5 ft. base and

9 feet high. For the above transformed voltage, the General Electric Company's K2 switch will be used. This is a wall type switch and takes about two feet of space. The step-down transformers for station use are of the usual 2300 - 220 volt type and may also be mounted against the wall.

For the generator excitation, two machines will be equipped with belt-driven exciters, these to be used in starting up the plant. A motor-generator set will be used to furnish direct current when the plant is running.

For each turbine an oil pressure governor will be necessary.

The control board for the various machines and switches will be of the desk type. A small d.c. board will also be necessary.

With these features in mind, the general layout of the plant is as follows.

The necessary spacing between centers of turbines is 12' 0". Allowing 4' 0" clearance

between alternator and wall, makes the inside of the building 50' 0" in length.

The distance from the axis of the turbine to the end of the draft tube has already been fixed at 24' 0". Adding to this a 4 foot clearance to the wall, gives an inside width of 32' 0". The curtain walls are 12 inches in thickness, and a veneer of brick will be placed around the columns on the outside. This gives a net length and width of foundations of 34' 0" x 52' 0", with an additional 4 inches at columns.

On the intake side of the power house, there will be, at the floor level, a 7' 0" projection, tapering to 8' 0" at the base, in which will be placed the butterfly control valves for each distributor pipe. These valves will be placed in manholes with the control mechanism above.

Upon this substructure, is to be erected a superstructure of reinforced concrete columns

and beams, with 12 inch brick curtain walls. The columns will carry a continuous beam on which will be placed the rail for a 5-ton traveling crane.

Steel window sash will be used, and a 10" x 12" double steel door. Steel trusses will be used to support the roof.

On the interior of the power house, there will be a balcony extending the length of the building opposite the alternators. Beneath this balcony, in separate 9 ft. rooms, will be located the step-up transformers for each machine. The remaining space will be given over to a wash room and office. On the balcony will be located the high-tension oil switches, the d.c. switch board, the desk control board, and the station step-down transformers. This balcony will be 12' 0" high. A standard pipe railing and an iron stairway are to be provided. The balcony is to be of concrete slab construction, resting on concrete partition

walls and upon a six inch brick wall at the ends and back of the balcony.

Column Design

The columns will be set on 12' 0" centers and will have an unsupported length of 28 ft. on that face parallel to the length of the building. Assuming that $l/d = 15$, the least width of column at right angles to the unsupported face is $d = 28 \times 12/15 = 22.4$ inches. The column thickness in this direction will be taken as 24 inches. The columns will carry the reactions of the roof load and the crane load of 5000 lbs. (5-ton crane). The roof load is assumed to consist of

Snow load	25#	sq.	ft.
Gravel roofing on 3" tile	60#	"	"
Total	85#	"	"

The roof will be only slightly pitched, and therefore no wind load is considered. The total area served by one column is 12' 9" x 16' 0" = 202 sq.ft. The total weight per

column is then 202 x 85 = 17,350 lbs. The clearance necessary for the crane is 12 in. making an eccentric distance of 6 inches for the crane load. Taking moments about the outside edge of the column gives

$$\frac{5000 \times 18 + 17,350 \times 6}{22,350} = 8.68 \text{ inches}$$

The eccentric distance of the total load is therefore 12.00 - 8.68 = 3.32 inches. The eccentricity is $e/h = 3.32/24 = .138$ inches. The moment of the load is

$$M = 22,350 \times 3.32 = 74,300 \text{ inch lbs.}$$

Using $p = .005$, from Plate XIII, Turneaure and Maurer's Principles of Reinforced Concrete Construction, $M/bh^2f_c = .09$ or

$f_c = 74,300/18 \times 24 \times 24 \times .09 = 79.5$ lbs.

This value is, of course, very low but it is limited by the unsupported length of the column and the requirements of support for the crane.

The crane rails will rest on concrete

beams spanning from column to column, at a distance of 22 feet from the floor. Above the sill where the beam rests, the roof load is carried axially by a 12 x 18 inch column, continuous with the main column. The area is therefore 246 square inches and the stress in the concrete is 17,350/246 = 80.4 lbs. (not considering the reinforcing) or

$$A = \frac{P}{f_c\left[1 + (n-1)p\right]}$$

where A = area of concrete, f_c = stress in concrete, n = 15, p = .01, P = load = 17,350

Hence

$$f_c = \frac{17,350}{216\ (1+14)\ .01} = 70.6 \text{ lbs.}$$

The columns will therefore be 24 x 18 inches. The steel in the lower portion will be

.01 x 24 x 18 = 4.32 sq. inches

and 3 - 7/8" sq. twisted rods, spaced 7" on centers will be used in each 18" face. The area of these is 4.59 sq. inches. In the upper portion of the columns which carries the roof trusses, the area required is

.01 x 12 x 18 = 2.16 sq. inches and 2 - 3/4" sq. twisted rods spaced 14" centers will be used in each 18 inch face. A = 2.25 7/8" sq. twisted rods will be placed in the substructure at the proper points so that the column steel may be spliced to these later.

Design of Crane Beam

In the design of the beam to carry the crane, allowance must be made for impact due to the moving of the crane, and there must also be taken into consideration the maximum load which the beam will be called upon to carry - obviously when the load is close to either wall. To take care of impact, 100% will be allowed; that is, f_c will be 300 and f_s = 8000, which is half their usual values. For these values, R = 48 and p = .0065 from Plate III, page 277 of Turneaure and Maurer. Limitations in design make it impossible to bring the crane load less than three feet from the wall. For this position, the reactions

are 9000 lbs and 1000 lbs and the maximum moment is

$$M = Wl/4 = 9000 \times 12.75 \times 12 \,/\, 4$$

$$= 345{,}000 \text{ inch pounds.}$$

Hence

$$d = \sqrt{\frac{345000}{48 \times 12}} = 25 \text{ inches}$$

$A_s = 25 \times 12 \times .0065 = 1.95$ sq. inches

4 - 3/4" sq. twisted rods spaced 3-1/2" ctrs. will be sufficient. The shear = 9000 lbs. $v = 9000/25 \times 12 = 33$ lbs. The beam will therefore be made 12" x 28", allowing 3" below the center line of the steel.

Design of Lintels

Over the windows, lintels will be required to carry the brick curtain wall above. The height of the curtain wall from the top of the window is 12' 0"; the weight per cubic foot is 140 lbs.; the thickness of the wall is 12 inches. There will, therefore, be a uniform load of 140 x 12 = 1680 lbs over the lintel, or a moment of $\frac{1680 \times 10.75 \times 12}{8} =$

29,800 inch lbs.

$$d = \sqrt{\frac{298000}{98 \times 12}} = 16 \text{ inches}$$

The total depth will be 18 inches.

$A_s = 16 \times 12 \times .0075 = 1.44$ sq. inches

4 - 7/8" round rods, 3" centers give an area of 1.47, and will be used.

Design of Floor Slab for Balcony

A dead load of 300 lbs per sq. foot is assumed for the switchboard, switchboard equipment and bench board. The transformer room walls are 9'0" center to center and therefore the moment to be designed for is

$$M = \frac{12}{12} \times 300 \times 9 \times 9 = 24300 \text{ " lbs.}$$

From table 21, part 6, on page 297 of Turneaure and Maurer, a 6" slab on an 8.4 foot span has a resisting moment of 26,700 in.Lbs. A nine foot span should therefore be safe. For such a slab, the thickness of concrete below the steel is 1-1/4 inches and the srea of steel required per foot is .427 sq. in.

1/2" sq. twisted rods, spaced 7" centers give an area of .43 sq. inches per foot. There will be one span of 15 feet. This space will be used for station transformers, etc. and the load will not exceed 50 lbs. per square foot for which reason the depth of slab may remain the same.

Design of Supporting Walls for Balcony

With the 300 lbs. assumed for a slab load on the balcony, the reaction on the supporting walls is 2700 lbs. Assuming a one foot section as a short column, unreinforced, and a height of 12' 0"

$$l/d = 15 \qquad d = \frac{12 \times 12}{15} = 10 \text{ in.}$$

f_c = 2700/12 x 10 = 23 lbs. per sq. inch

Although this is designed as an unreinforced wall, steel equal to .5% of the area of the wall will be used, or 120 x .005 = .6 sq.in. 3/4" sq. twisted rods spaced 12" centers gives an area of .56 in. which is sufficient.

At the two ends of the balcony and along the back, the brick curtain wall will be made 18" thick to allow bearing surface of 6" for the balcony in addition to the concrete supporting walls.

BIBLIOGRAPHY

Gelpke and Van Cleve:

Hydraulic Turbines

Mead, Daniel W.

Water Power Engineering

Turneaure and Maurer

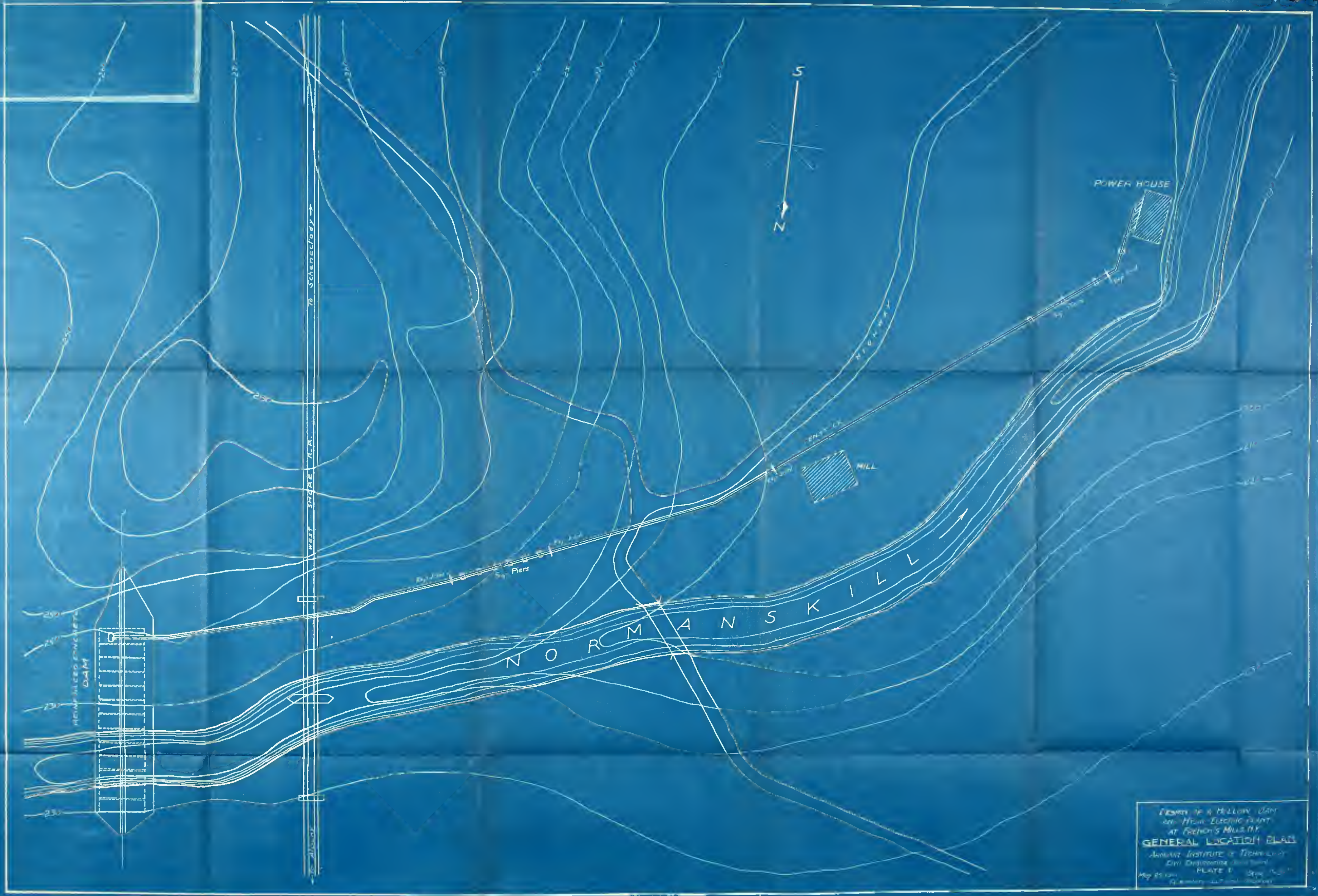
Principles of Reinforced Concrete Const.

Hillberg, A. G.

Scroll Case Design, Eng.N. Oct.2,1915

Marran, Vincent P.

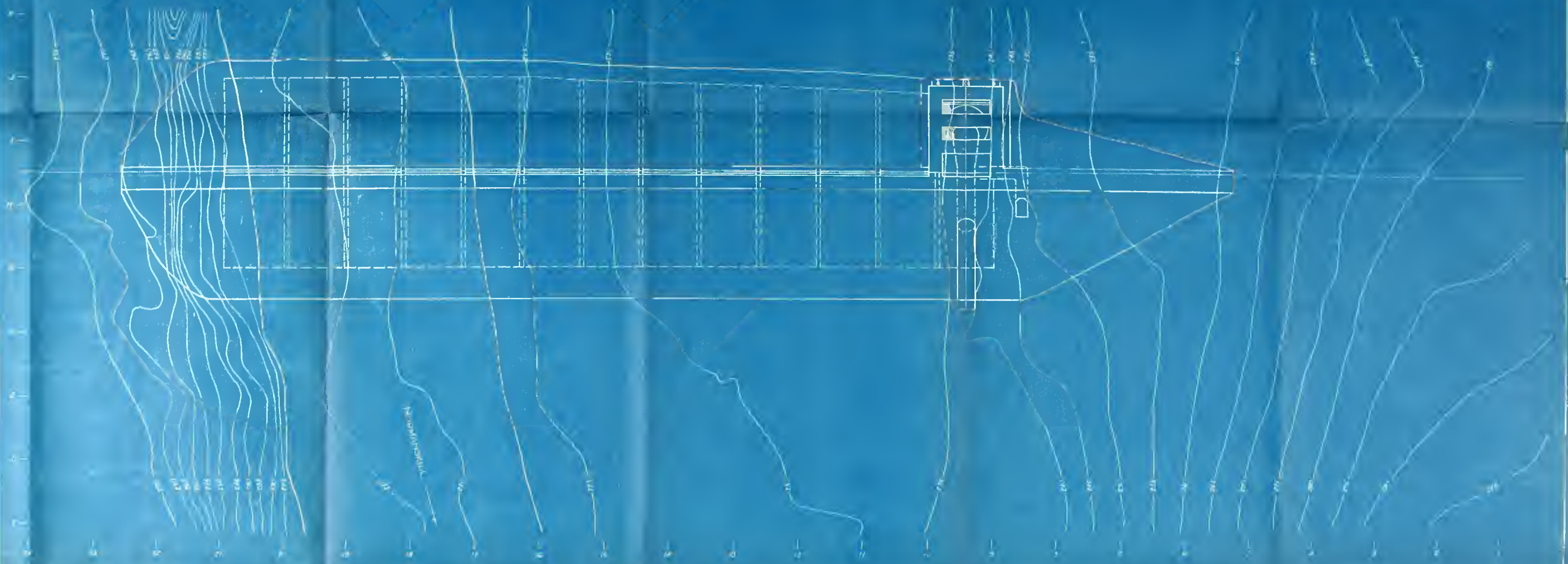
Penstock Design, Eng.Rec. Mar. 20,1915.



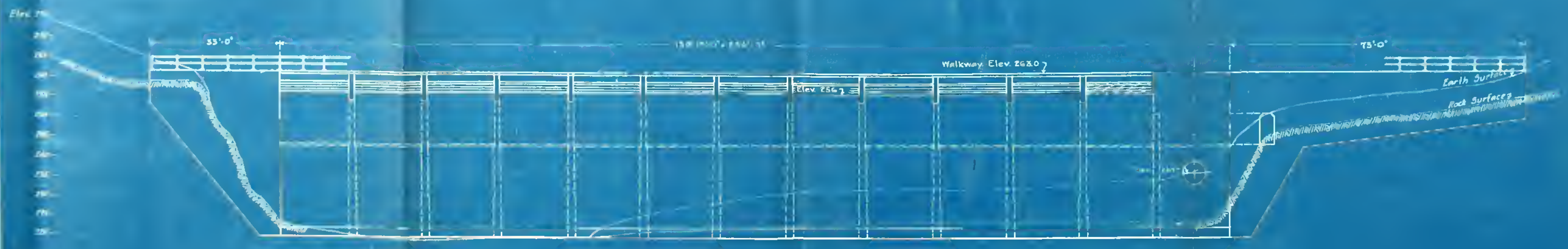
DESIGN OF A HOLLOW DAM
AND HYDRO ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.

GENERAL LOCATION PLAN

ARMOUR INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT
PLATE I
May 25 1911 Scale [illegible]
[illegible]



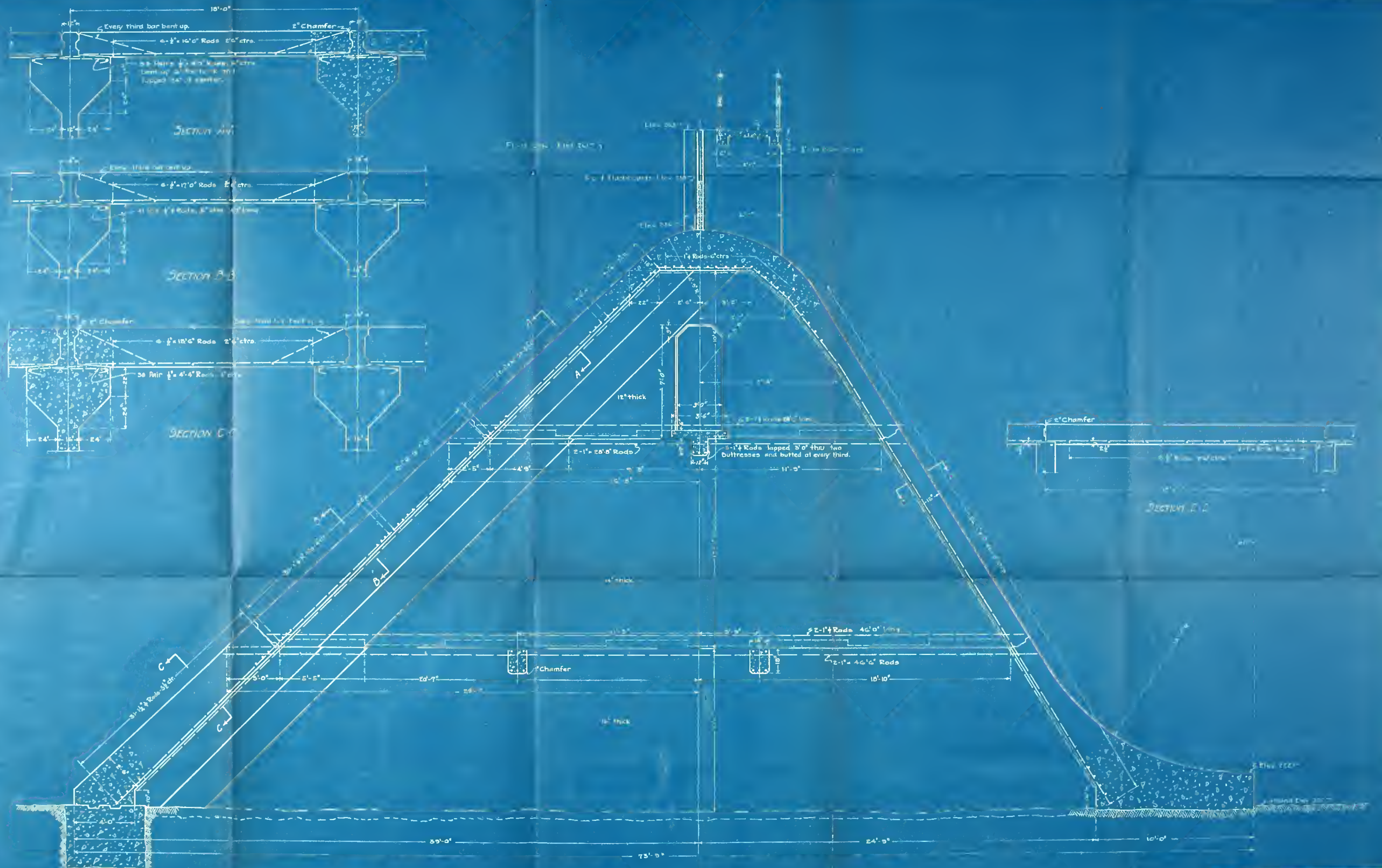
• TOPOGRAPHY AT DAM-SITE AND GENERAL PLAN •



ELEVATION AND
• CROSS-SECTION OF STREAM ON ℄ OF DAM •

DESIGN OF A HOLLOW DAM
AND HYDRO-ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.
PLAN & ELEVATION OF DAM

ARMOUR INSTITUTE OF TECHNOLOGY
Civil Engineering Department
PLATE I
May 26, 1911 Scale [illegible]
[illegible] L. I. Dawson [illegible]



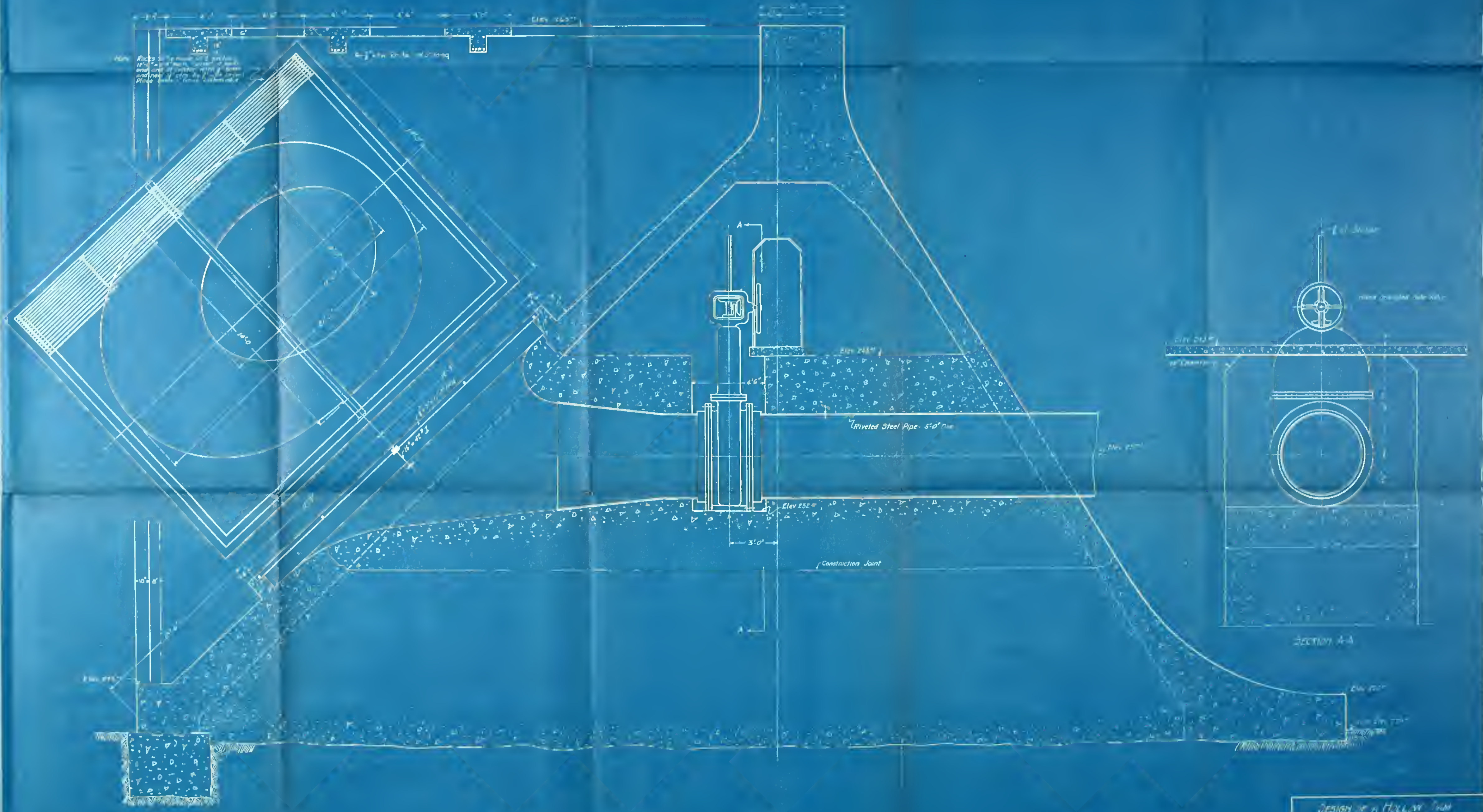
Design of a Hollow Dam
and Hydro-Electric Plant
at French's Mills, N.Y.

TYPICAL SECTION OF DAM

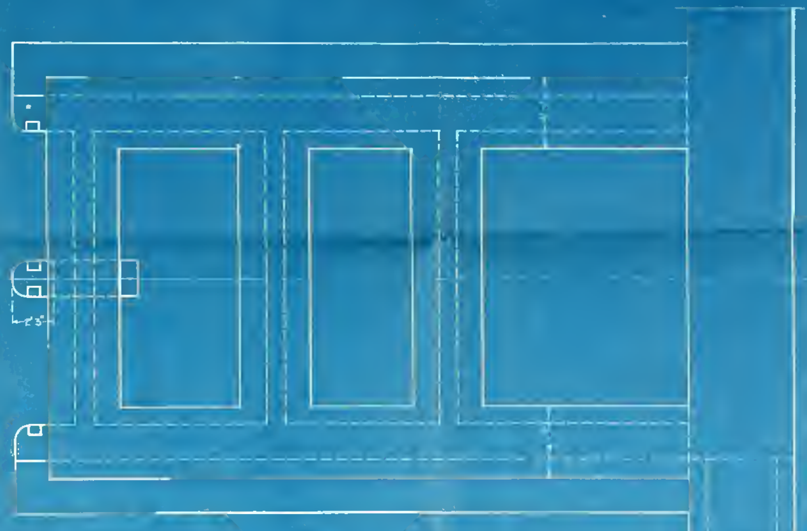
Armour Institute of Technology
Civil Engineering Department
Plate II

May 25 1910 Scale ¼"=1 ft.

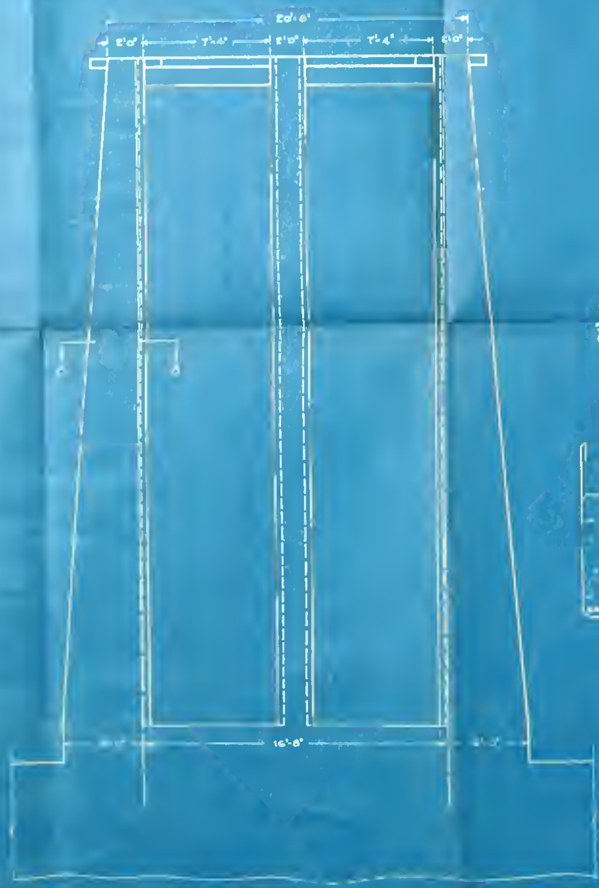
R. Armstrong - L.L. Brown - [illegible]



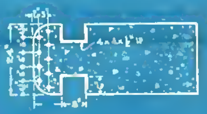
DESIGN OF A HOLLOW DAM
AND HYDRO-ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.
DETAILS OF INTAKE
ARMOUR INSTITUTE OF TECHNOLOGY
Civil Engineering Department
PLATE
May 26, 1916



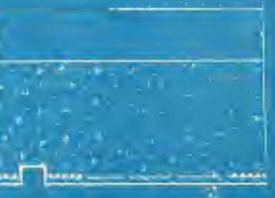
· PLAN ·



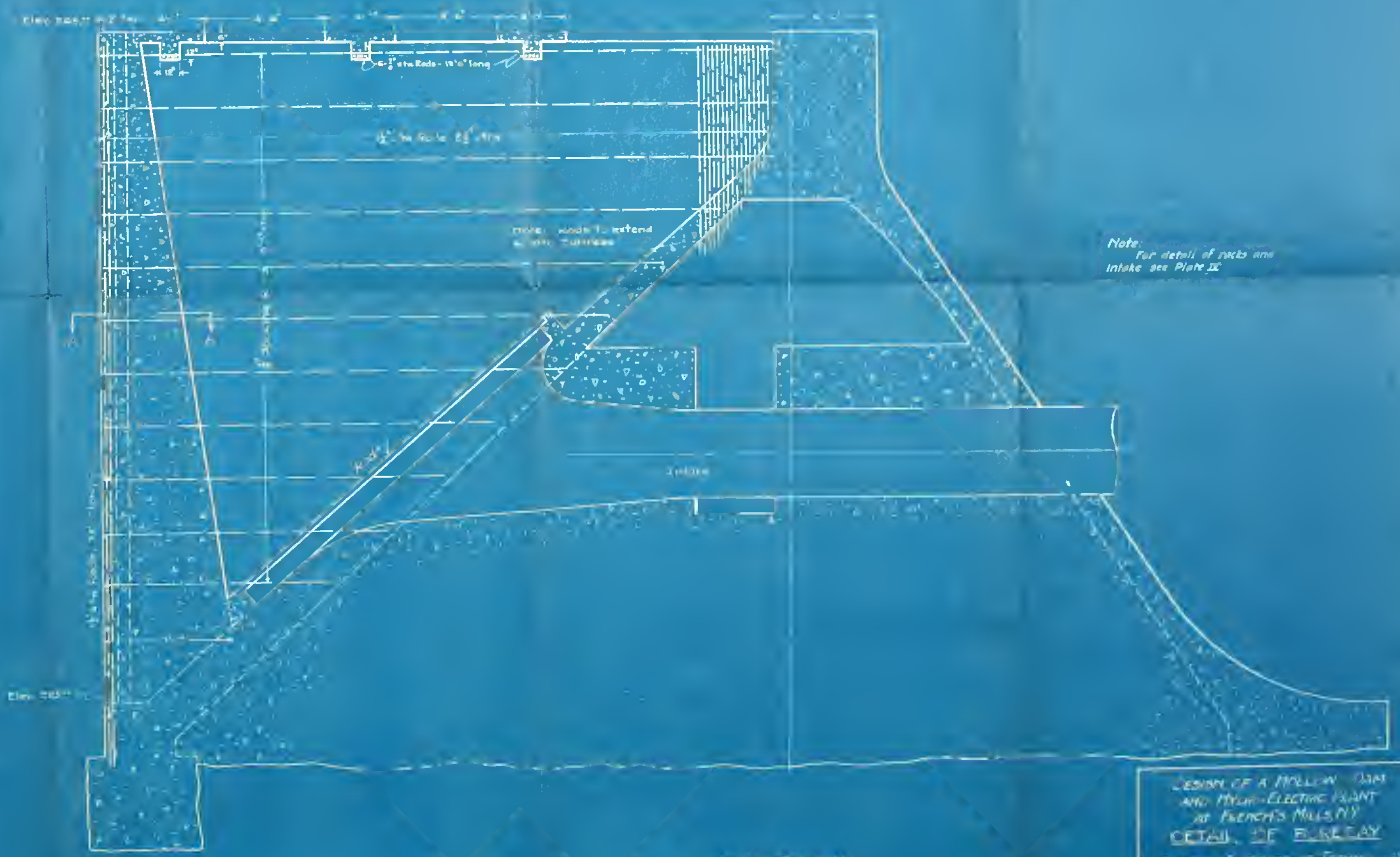
· END · ELEVATION ·



SECTION A-A



SECTION B-B



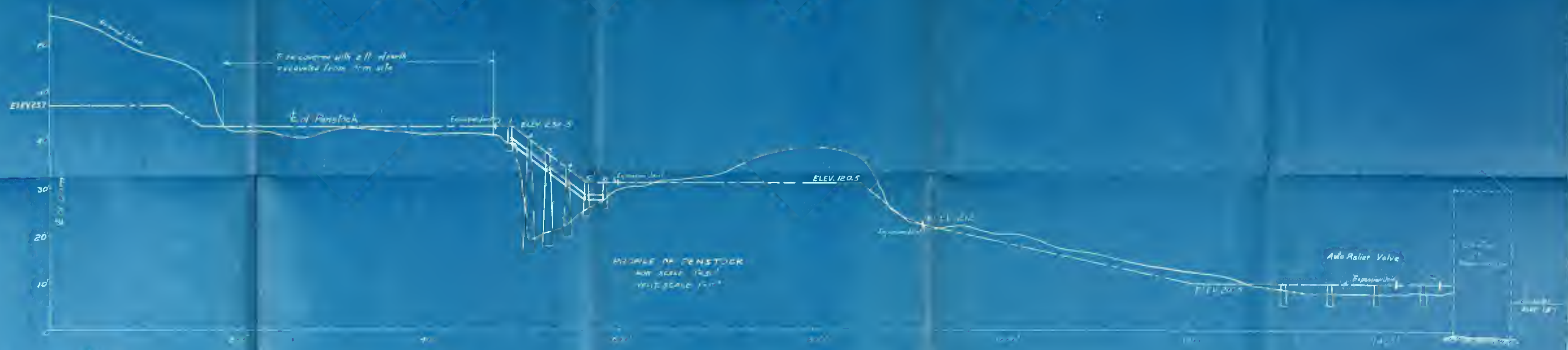
· CROSS · SECTION ·

Note:
For detail of racks and intake see Plate IX

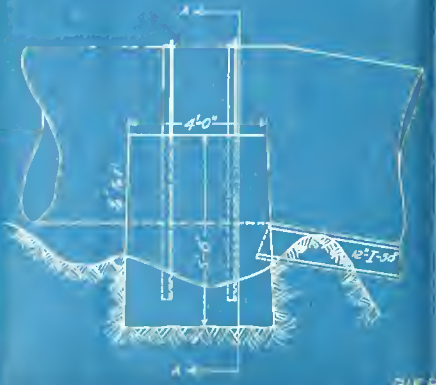
DESIGN OF A HOLLOW DAM
AND HYDRO-ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.
DETAIL OF FOREBAY

ARMOUR INSTITUTE OF TECHNOLOGY
Civil Engineering Department
PLATE X

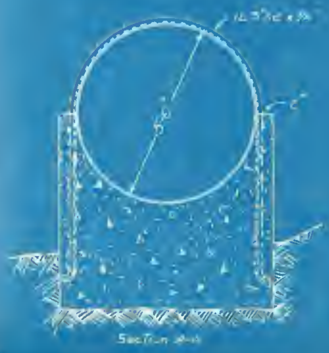
May 26, 1916 [illegible]
[illegible]



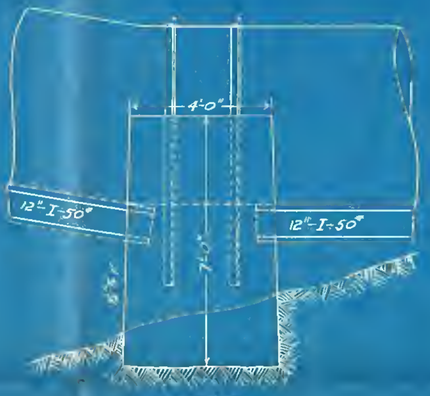
PROFILE OF PENSTOCK



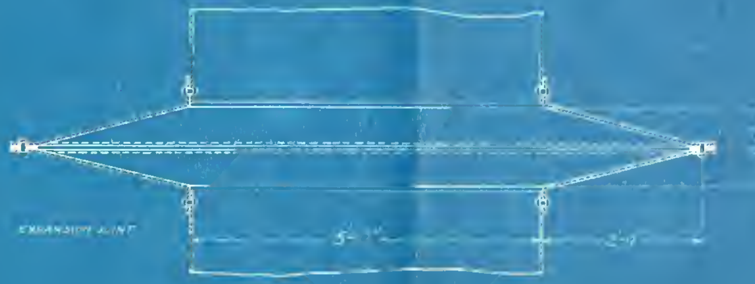
PIER #1



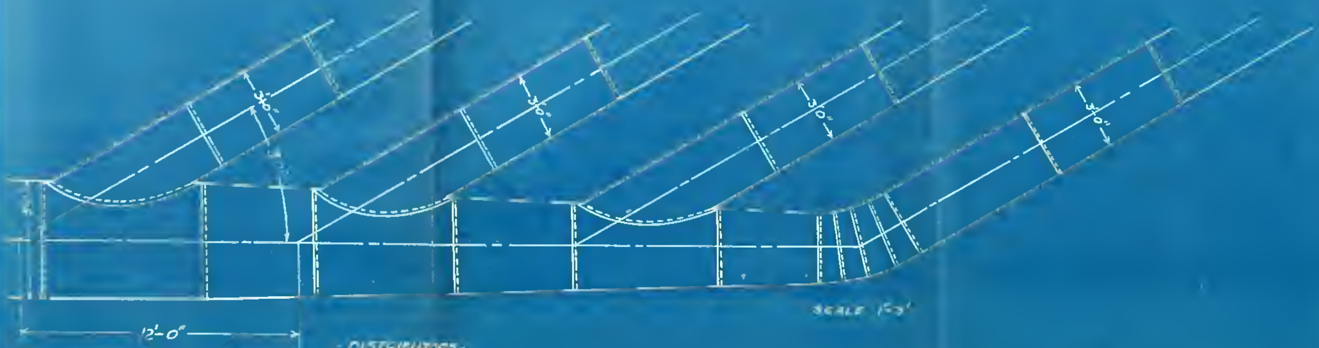
SCALE ¼"=1'



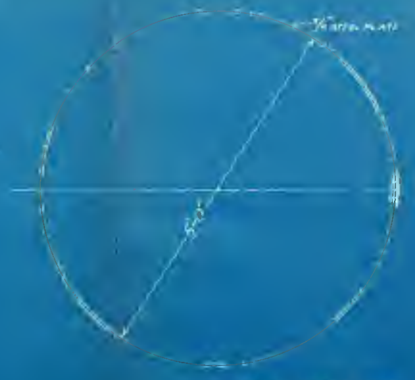
PIER #5



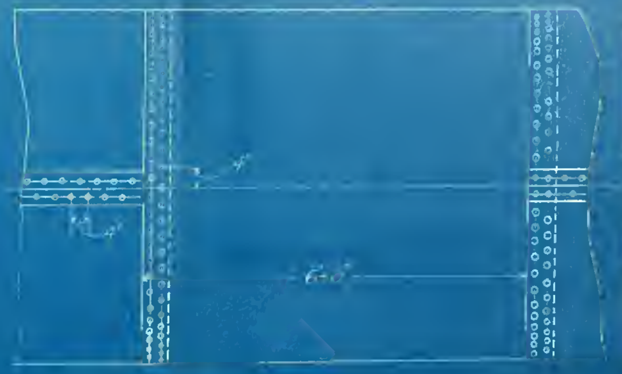
SCALE 1"=1'



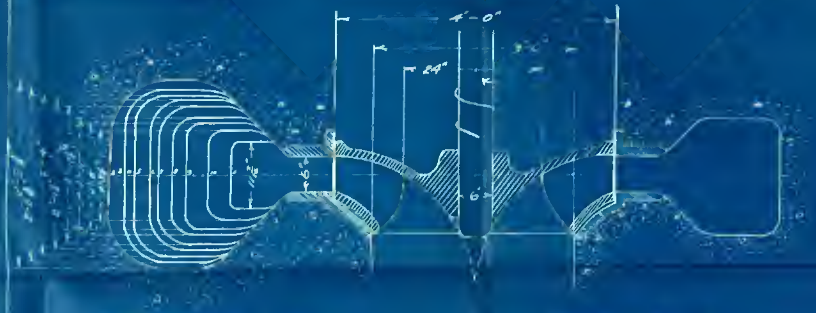
- DISTRIBUTORS -



STEEL, PLATE PIPE

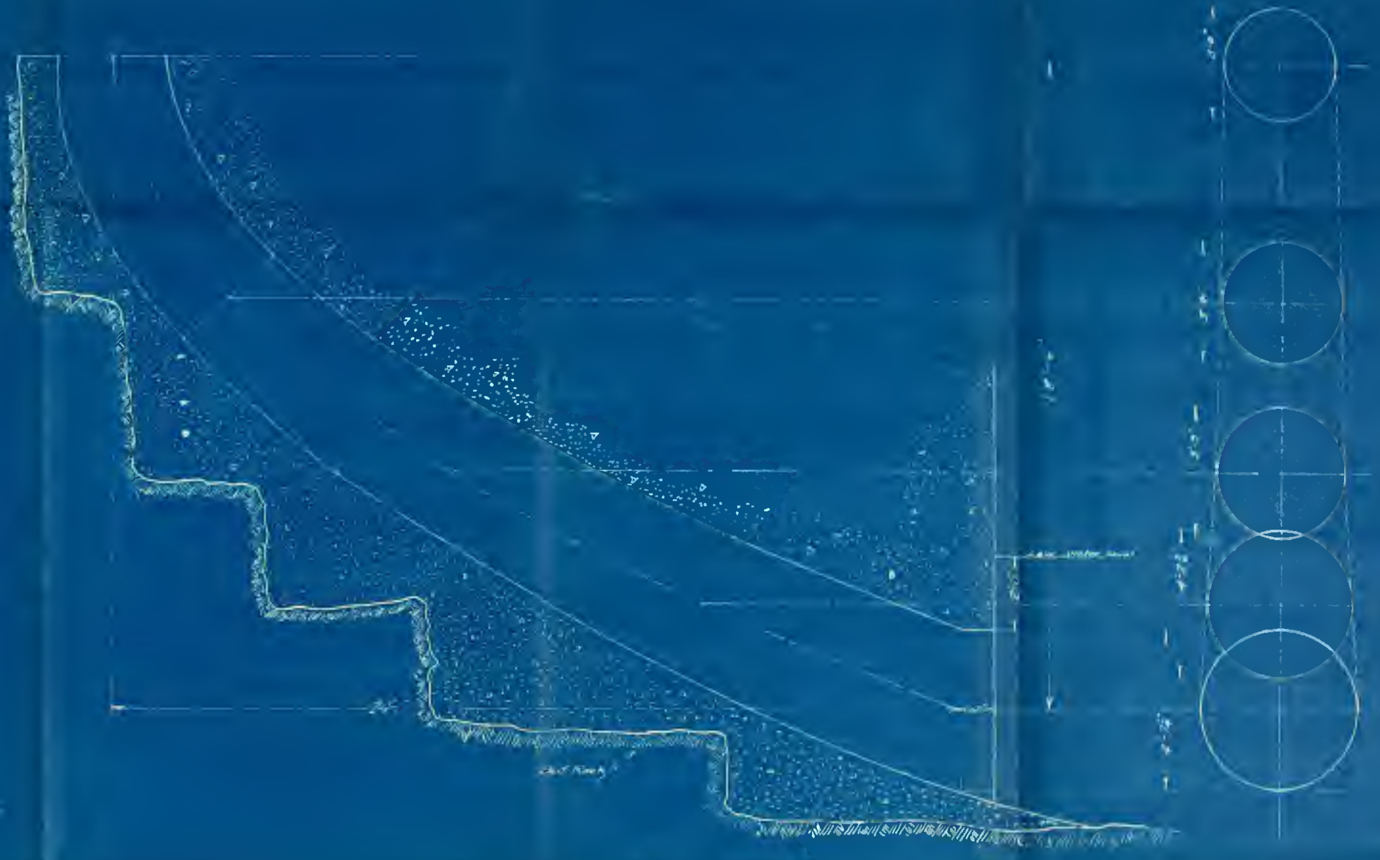


DESIGN OF A HOLLOW DAM
AND HYDRO ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.
PROFILE & DETAILS OF PENSTOCK
ARMOUR INSTITUTE OF TECHNOLOGY
Civil Engineering Department
PLATE [illegible]
May [illegible] Scale as shown
[illegible]

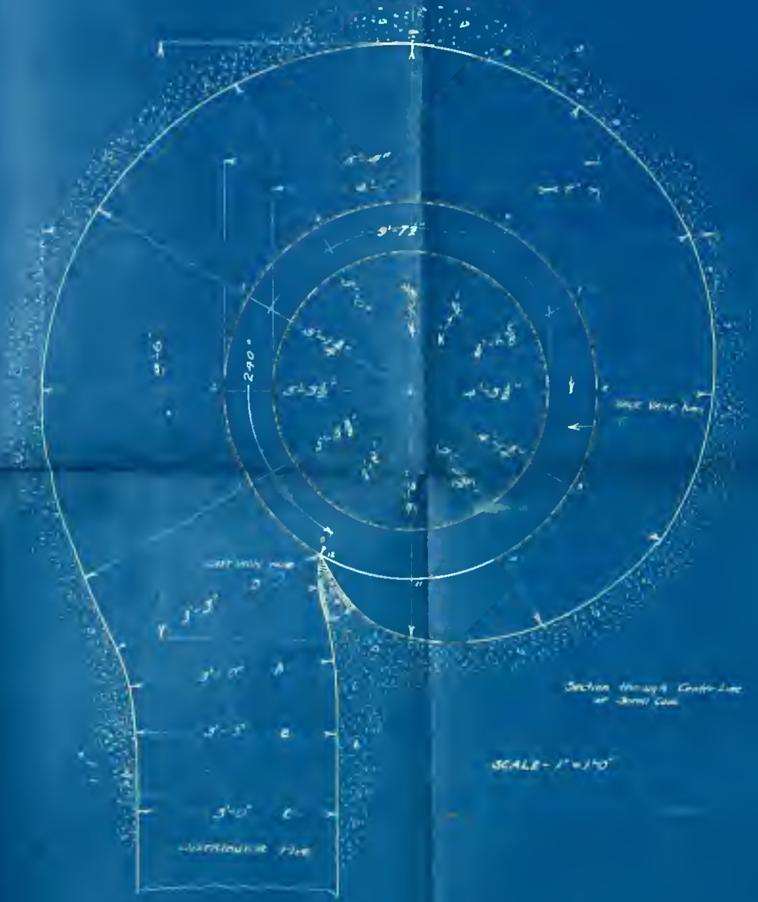


NOTE - The above sections [illegible] have been [illegible] They correspond to the [illegible] sections below.

Section through Turbine and Scroll Case

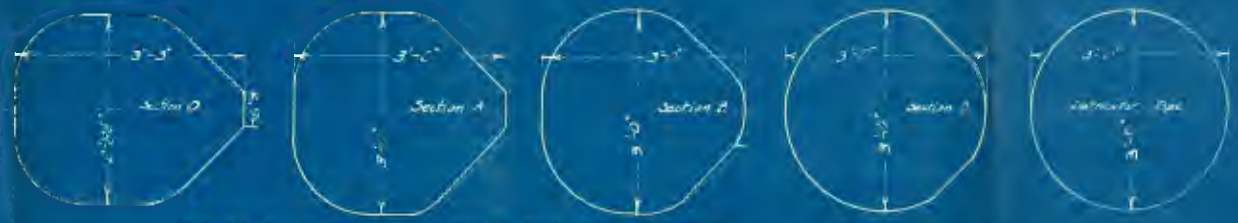


Section of Draft Tube
SCALE 1/2" = 1'-0"



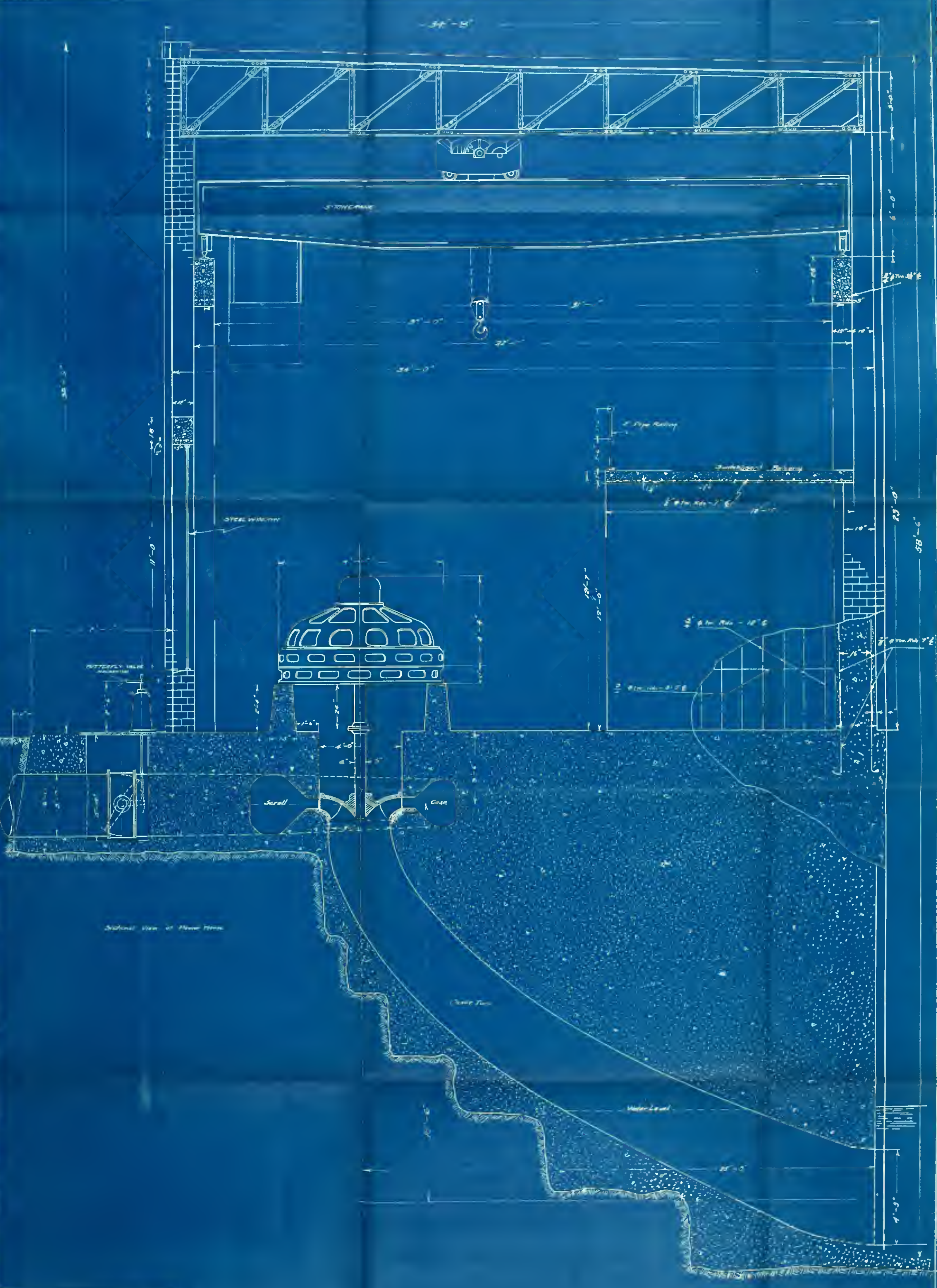
Section through Center-Line of Scroll Case

SCALE - 1" = 1'-0"

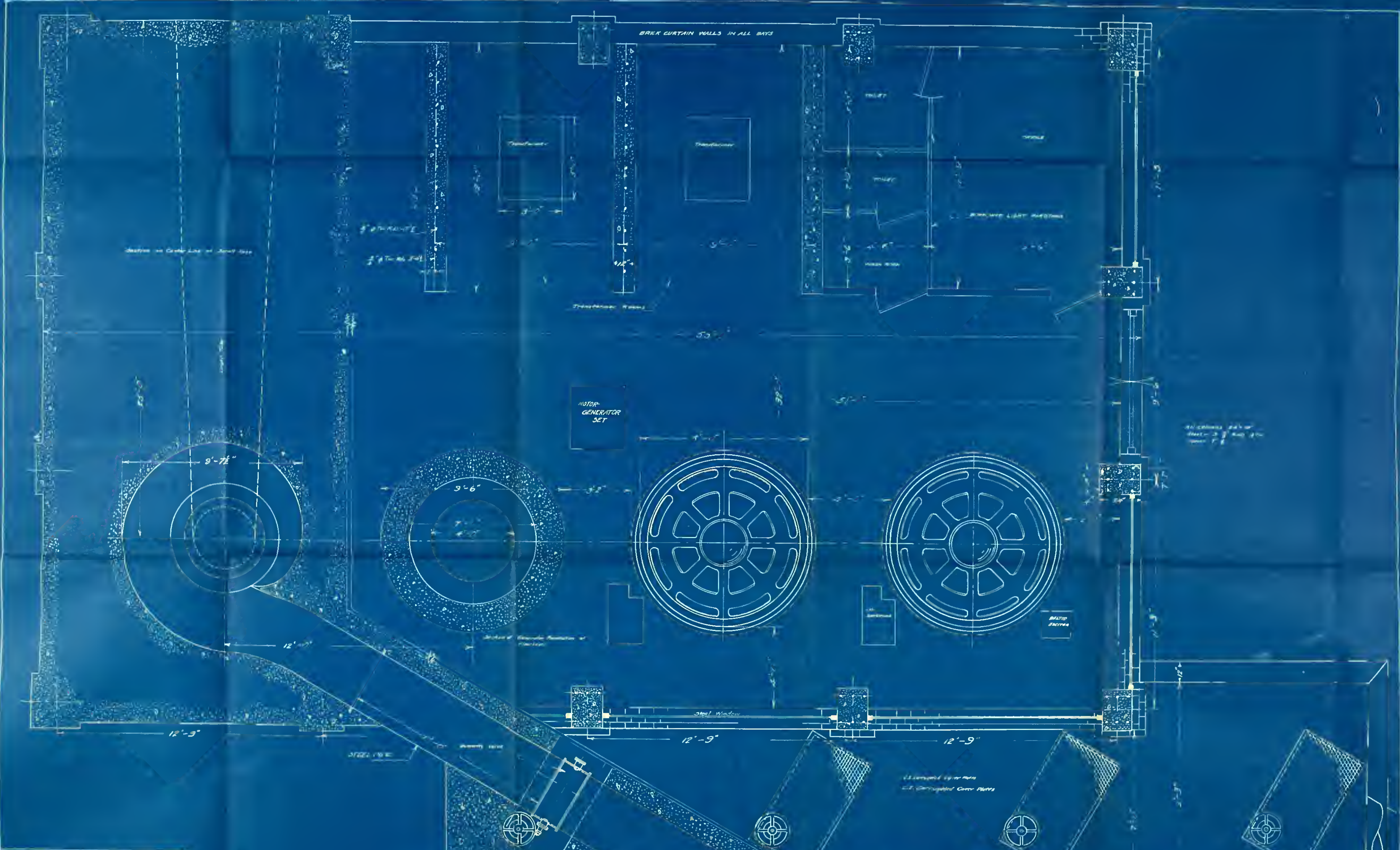


Equal-Area Transformation Sections — Distributor Pipe to Scroll Case Entrance
Scale - 1" = 1'-0"

DESIGN OF A HOLLOW DAM
AND HYDRO-ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.
SCROLL CASE AND DRAFT TUBE
ARMOUR INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPT.
PLATE XXI
[illegible]



DESIGN OF A HOLLOW DAM
AND HYDRO-ELECTRIC PLANT
AT FRENCH'S MILLS N.Y.
ELEVATION OF POWER PLANT
ARMOUR INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT
THESIS VIII
MAY 25 [illegible] SCALE [illegible]
[illegible]



DESIGN OF A HOLLOW DAM
AND HYDRO-ELECTRIC PLANT
AT FRENCH'S MILLS, N.Y.

PLAN OF POWER PLANT

ARMOUR INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT
PLATE IX

MAY 25 1914 Scale ¼"=1'-0"

[illegible]